S.I.A.

REPORT

OF THE

FORTY-FIRST MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

EDINBURGH IN AUGUST 1871.

LONDON:
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ALERE FLAMMAM.

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x, *after* line 32, *insert* Anatomy and Physiology.

xi, „ 37, „ Ethnology and Anthropology.

xv, „ 25, „ Address by Mr. John Evans to the Department of Ethnology and Anthropology.

xxxii, line 31, *for* Glasgow *read* Edinburgh.

129, Transactions of Sections, *after* line 11, *insert* Anatomy and Physiology.

143, „ „ „ „ 35, „ Ethnology and Anthropology.

ERRATUM IN THE PRESENT VOLUME.

Page 177, Transactions of the Sections, line 33, *for* 0′·58 *read* 0″·58.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be pub-

lished after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis,* or to *purchase* it at reduced (or Members') price, according to the following specification, viz. :—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices,* viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain,* at one-third of the Publication Price. Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the Arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

Class B. Temporary Members.

1. Presidents for the time being of any Scientific Societies publishing Transactions or, in his absence, a delegate representing him. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

*Organizing Sectional Committees**.

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections†, and of preparing Reports thereon,

* Passed by the General Committee, Edinburgh, 1871.

† *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be

and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first Meeting.

An Organizing Committee may also hold such preliminary Meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to settle the terms of their Report, after which their functions as an Organizing Committee shall cease.

Constitution of the Sectional Committees.*

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee †. The List of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the

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read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting*. It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before ...., addressed thus—"General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ...." If it should be inconvenient to the Author that his Paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note.

* Passed by the General Committee, Edinburgh, 1871.

† This and the following sentence were added by the General Committee, 1871.

Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printers, who are charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xix), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant-General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices Regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in Science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next meeting of the Association) forward to the General

Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, W. Spottiswoode, Esq., 50 Grosvenor Place, London, S.W., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, be commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket, signed by the Assistant-General Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the Programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London. LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson D.D.,	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. York, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. Cambridge, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. Southampton, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford Oxford, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. Swansea, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. Birmingham, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews Edinburgh, July 21, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal Ipswich, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L. F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, LL.D.
RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural-History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, M.A., Esq. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. .. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Reverend the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford .... BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Reverend the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. J. T. Chance, Esq. F. Osler, Esq., F.R.S. The Rev. Charles Evans, M.A.	William Mathews, Esq., jun., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. .... NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. .... DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh. James D. Forbes, LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonards, University of St. Andrews	J. Henderson, Esq., jun. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.

JOSEPH DALTON HOOKER, M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk. Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge. Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge. Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. The Earl of Devon. The Right Hon. Sir Stafford H. Northcote, C.B., Bart., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. The Earl of Derby, LL.D., F.R.S. Sir Philip De M. Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.SS.L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. The Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice General of Scotland. Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, M.P., C.B., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.SS.L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR. W. B. CARPENTER, LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord Lieutenant of the County of Sussex. The Duke of Norfolk. The Right Hon. the Duke of Richmond, K.G., P.C., D.C.L. The Right Hon. the Duke of Devonshire, K.G., D.C.L., F.R.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. J. Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place.	Presidents.	Secretaries.

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

1832. Oxford	Davies Gilbert, D.C.L., F.R.S....	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S............	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S..........	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

1835. Dublin	Rev. Dr. Robinson..................	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R.S....	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool ...	Sir D. Brewster, F.R.S............	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle...	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S.	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S.	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth...	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
1844. York	The Earl of Rosse, F.R.S..........	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge..	The Very Rev. the Dean of Ely .	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford	Rev. Prof. Powell, M.A., F.R.S. .	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh..	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich......	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull	The Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S. ...	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.

Date and Place.	Presidents.	Secretaries.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen ...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford	Rev. B. Price, M.A., F.R.S.......	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester.	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge..	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle...	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee......	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S...	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool ...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh .	Prof. P. G. Tait, F.R.S.E.	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford	John Dalton, D.C.L., F.R.S.......	James F. W. Johnston.
1833. Cambridge..	John Dalton, D.C.L., F.R.S.......	Prof. Miller.
1834. Edinburgh...	Dr. Hope..............................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming...............	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle...	Rev. William Whewell, F.R.S....	Prof. Miller, R. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Golding Bird, M.D., Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S. ...	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester.	John Dalton, D.C.L., F.R.S.......	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. R. Playfair, E. Solly, T. H. Barker.
1845. Cambridge..	Rev. Prof. Cumming...............	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.

Date and Place.	Presidents.	Secretaries.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S..........	R. Hunt, G. Shaw.
1850. Edinburgh .	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S....	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S..	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool...	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S..	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen ...	Dr. Lyon Playfair, C.B., F.R.S..	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester.	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge .	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle...	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S. ...	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S. ...	Prof. A. Crum Brown, M.D., Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, M.D., A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge .	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh .	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography*. R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*. Captain H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography*. Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography*. Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*. G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.

Date and Place.	Presidents.	Secretaries.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth..	H. T. De la Beche, F.R.S.	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge .	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	Robert A. Austen, J. H. Norten, M.D., Prof. Oldham.—*Geography.* Dr. C. T. Beke.
1847. Oxford	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh *	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Professor Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S...	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.	Prof. Harkness, William Lawton.
1854. Liverpool . .	Prof. Edward Forbes, F.R.S. ...	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S.	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S.	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide ...	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen ...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S., &c.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.......	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle ...	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.

* At the Meeting of the General Committee held in Edinburgh, it was agreed "That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section," for Presidents and Secretaries of which see page xxxvi.

Date and Place.	Presidents.	Secretaries.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee......	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh ..	Prof. A. Geikie, F.R.S., F.G.S...	R. Etheridge, J. Geikie, J. McKenny Hughes, L. C. Miall.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford	Rev. P. B. Duncan, F.G.S.	Rev. Prof. J. S. Henslow.
1833. Cambridge*	Rev. W. L. P. Garnons, F.L.S....	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham........................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin	Dr. Allman...........................	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool..	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle...	Sir W. Jardine, Bart...............	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Brimingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S..	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. The Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford.......	H. E. Strickland, M.A., F.R.S....	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see pp. xxxv, xxxvi.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.............	Dr. Lankester, Dr. Russell.
1850. Edinburgh..	Prof. Goodsir, F.R.S. L. & E. ...	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich......	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S....	Robert Harrison, Dr. E. Lankester.
1854. Liverpool ...	Prof. Balfour, M.D., F.R.S.......	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E. ...	William Keddie, Dr. Lankester.

* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xxxv.

Date and Place.	Presidents.	Secretaries.
1856. Cheltenham.	Thomas Bell, F.R.S., Pres.L.S....	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds.........	C. C. Babington, M.A., F.R.S....	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen ...	Sir W. Jardine, Bart., F.R.S.E..	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester..	Prof. C. C. Babington, F.R.S. ...	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge...	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle ...	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath	Dr. John E. Gray, F.R.S.	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S.	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY*.

1866. Nottingham.	Prof. Huxley, LL.D., F.R.S.—*Physiological Dep.* Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.* Alfred R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee	Prof. Sharpey, M.D., Sec. R.S.—*Dep. of Zool. and Bot.* George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S.—*Dep. of Physiology.* W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S.—*Dep. of Bot. and Zool.* C. Spence Bate, F.R.S.—*Dep. of Ethno.* E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, M.D., E. Ray Lankester, Professor Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. Anat. and Physio.* Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.* J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.* Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropo.* Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge...	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh...	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E. (UNTIL 1847.)—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol......	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool ...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.

* At the Meeting of the General Committee at Birmingham, it was resolved:—"That the title of Section D be changed to Biology;" and "That for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' be substituted."

Date and Place.	Presidents.	Secretaries.
1838. Newcastle ...	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D...............	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec.R.S. ...	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester.	Edward Holme, M.D., F.L.S. ...	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork.........	Sir James Pitcairn, M.D.	Dr. John Popham, Dr. R. S. Sargent.
1844. York.........	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

SECTION E.—PHYSIOLOGY.

1845. Cambridge .	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S..........	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford* ...	Prof. Ogle, M.D., F.R.S..........	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S. ...	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen ...	Prof. Sharpey, M.D., Sec.R.S. ...	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester.	Dr. John Davy, F.R.S.L. & E....	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge .	C. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle...	Prof. Rolleston, M.D., F.R.S. ...	Dr. D. Embleton, Dr. W. Turner.
1864. Bath	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm†.	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxxii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard.........................	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh..	Vice-Admiral Sir A. Malcolm ...	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S. ...	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.

* By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of "Section D—Zoology and Botany, including Physiology" (see p. xxxiv). The Section being then vacant was assigned in 1851 to Geography.

† *Vide* note on preceding page.

Date and Place.	Presidents.	Secretaries.
1857. Dublin	Rev. Dr. J. Henthawn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen ...	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Professor Geddes, Dr. Norton Shaw.
1860. Oxford	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lempriere, Dr. Norton Shaw.
1861. Manchester.	John Crawfurd, F.R.S.	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge .	Francis Galton, F.R.S.	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle...	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir R. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee......	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh.	Colonel Yule, C.B., F.R.G.S. ...	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge .	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh .	Sir Charles Lemon, Bart.	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Charles Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle...	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, F.R.S., M.P.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester.	G. W. Wood, M.P., F.L.S.	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P.	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge .	Rt. Hon. The Earl Fitzwilliam...	J. Fletcher, W. Cooke Tayler, LL.D.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.

Date and Place.	Presidents.	Secretaries.
1847. Oxford	Travers Twiss, D.C.L., F.R.S. ...	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede
1849. Birmingham	Rt. Hon. Lord Lyttelton	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh ..	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. Stark.
1851. Ipswich......	Sir John P. Boileau, Bart.	J. Fletcher, Prof. Hancock.
1852. Belfast	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, Jun.
1853. Hull	James Heywood, M.P., F.R.S....	Edward Cheshire, William Newmarch.
1854. Liverpool ...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow	R. Monckton Milnes, M.P.	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P. ...	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock Newmarch, W. M. Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds.........	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen ...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S.	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge..	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle ...	William Tite, M.P., F.R.S.	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath..........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...............	R. Birkin, Jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich ...	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A. ..	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves.............	J. G. Fitch, James Meikle.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S....	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool ...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle ...	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robert Stephenson.	W. Carpmael, William Hawkes, Thomas Webster.
1840. Glasgow ...	Sir John Robinson..................	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.

Date and Place.	Presidents.	Secretaries.
1841. Plymouth...	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester.	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A.	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge..	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, Jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh..	Rev. Dr. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool ...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, Jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, Jun., H. M. Jeffery.
1857. Dublin	The Right Hon. The Earl of Rosse, F.R.S.	Prof. Downing, W. T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen ...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester.	J. F. Bateman, C.E., F.R.S.	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge..	William Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle ...	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.

List of Evening Lectures.

Date and Place.	Lecturer.	Subject of Discourse.
1842. Manchester.	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.

Date and Place.	Lecturer.	Subject of Discourse.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G. B. Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S.	Shooting-stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S.	The Dodo (*Didus ineptus*).
1848. Swansea	John Percy, M.D., F.R.S.	Metallurgical operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S.	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh.	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G. B. Airy, F.R.S., Astron. Roy.	Total Solar Eclipse of July 28, 1851.
1852. Belfast	Prof. G.G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.
1854. Liverpool	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. W. Thomson, F.R.S.	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen	Sir R. I. Murchison, D.C.L.	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S.	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S.	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Roy.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.

Date and Place.	Lecturer.	Subject of Discourse.
1863. Newcastle-on-Tyne.	Prof. Williamson, F.R.S.	The chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath	Prof. Roscoe, F.R.S................	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.............	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham.	William Huggins, F.R.S..........	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S..........	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S..........	The Geological origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S....	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S.......	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool ...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connexion with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S..................	On some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	On the Relation of Primitive to Modern Civilization.

Lectures to the Operative Classes.

1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich	Prof. Huxley, LL.D., F.R.S. ...	A piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S.	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.

Table showing the Attendance and Receipts

Date of Meeting.	Where held.	Presidents.	Old Life Members.	New Life Members.
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L. ...	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S. ..	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S....	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.	...	..
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S. .	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne ..	The Duke of Northumberland...	...	...
1839, Aug. 26 ...	Birmingham	The Rev. W. Vernon Harcourt .	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane ...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S....	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D.	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart. .	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton ...	149	3
1849, Sept. 12 ...	Birmingham	The Rev. T. R. Robinson, D.D. .	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Esq., Astron. Royal .	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S. ...	164	10
1853, Sept. 3 ...	Hull	William Hopkins, Esq., F.R.S. .	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S. ..	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D....	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds	Richard Owen, M.D., D.C.L. ...	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. The Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A.......	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Prof. Willis, M.A. ...	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne ..	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A....	287	40
1865, Sept. 6 ...	Birmingham	Prof. J. Phillips, M.A., LL.D....	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S. .	196	18
1869, Aug. 18 ...	Exeter..................	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D....	246	28

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting.	Sums paid on Account of Grants for Scientific Purposes.
Old Annual Members.	New Annual Members.	Associates.	Ladies.	Foreigners.	Total.		
						£ s. d.	£ s. d.
...	...	...	...	...	353	....	....
...	...	...	...	...	...	....	....
...	...	...	...	...	900	....	....
...	...	...	...	...	1298	....	20 0 0
...	...	...	...	...	...	....	167 0 0
...	...	...	...	...	1350	....	434 14 0
...	...	...	...	...	1840	....	918 14 6
...	...	...	1100*	...	2400	....	956 12 2
...	...	...	...	34	1438	....	1595 11 0
...	...	...	...	40	1353	....	1546 16 4
46	317	...	60*	...	891	....	1235 10 11
75	376	33†	331*	28	1315	....	1449 17 8
71	185	...	160	...	...	....	1565 10 2
45	190	9†	260	...	...	....	981 12 8
94	22	407	172	35	1079	....	830 9 9
65	39	270	196	36	857	....	685 16 0
197	40	495	203	53	1260	....	208 5 4
54	25	376	197	15	929	707 0 0	275 1 8
93	33	447	237	22	1071	963 0 0	159 19 6
128	42	510	273	44	1241	1085 0 0	345 18 0
61	47	244	141	37	710	620 0 0	391 9 7
63	60	510	292	9	1108	1085 0 0	304 6 7
56	57	367	236	6	876	903 0 0	205 0 0
121	121	765	524	10	1802	1882 0 0	330 19 7
142	101	1094	543	26	2133	2311 0 0	480 16 4
104	48	412	346	9	1115	1098 0 0	734 13 9
156	120	900	569	26	2022	2015 0 0	507 15 3
111	91	710	509	13	1698	1931 0 0	618 18 2
125	179	1206	821	22	2564	2782 0 0	684 11 1
177	59	636	463	47	1689	1604 0 0	1241 7 0
184	125	1589	791	15	3139	3944 0 0	1111 5 10
150	57	433	242	25	1161	1089 0 0	1293 16 6
154	209	1704	1004	25	3335	3640 0 0	1608 3 10
182	103	1119	1058	13	2802	2965 0 0	1289 15 8
215	149	766	508	23	1997	2227 0 0	1591 7 10
218	105	960	771	11	2303	2469 0 0	1750 13 4
193	118	1163	771	7	2444	2613 0 0	1739 4 0
226	117	720	682	‡45	2004	2042 0 0	1940 0 0
229	107	678	600	17	1856	1931 0 0	1572 0 0
303	195	1103	910	14	2878	3096 0 0	1472 2 6
311	127	976	754	21	2463	2575 0 0	

* Ladies were not admitted by purchased Tickets until 1843.
† Tickets for admission to Sections only. ‡ Including Ladies.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 14th September 1870 (commencement of LIVERPOOL Meeting) to 2nd August 1871 (EDINBURGH).

RECEIPTS.

		£	s.	d.
To Balance brought from last Account		232	5	3
Received for Life Compositions at Liverpool Meeting and since		488	0	0
„ Annual Subscriptions, ditto ditto		852	0	0
„ Associates' Tickets, ditto ditto		1103	0	0
„ Ladies' Tickets, ditto ditto		910	0	0
„ Dividends on Stock		235	0	0
„ Sale of Publications—viz.				
Reports	29 12 9			
Indexes to Report, &c.	2 0 6			
		31	13	3
„ Legacy from the late Mr. Alexander Robb		100	0	0
„ per Dr. Frankland, being balance of Grant made for investigating the Composition of Gases in Deep-well Waters		20	16	0
„ per Professor Huxley, being amount of Grant made for conducting Experiments on the Artificial Fecundation of Herrings		20	0	0
„ per Professor Williamson, being balance of Grant made for Reports on Standards of Electrical Resistance		45	1	2
„ from Committee on the Treatment and Utilization of Sewage, as per Recommendation of Liverpool General Committee		1201	9	3
		£5239	4	11

Examined and found correct.

WARREN DE LA RUE,
JOHN EVANS,
G. BUSK, } *Auditors.*

PAYMENTS.

		£	s.	d.
Paid Expenses of Liverpool Meeting, also Sundry Printing, Binding, Advertising, and Incidental Petty Expenses		427	3	6
„ Printing, Engraving, Report of 39th Meeting, Vol. XXXVIII. (Exeter)		589	12	2
„ Salaries (1 year)		420	0	0
„ Rent and Office Expenses (Albemarle Street)		93	8	8
„ Grants made at Liverpool Meeting, viz.—				
Maintaining Establishment of Kew Observatory	£600 0 0			
Monthly Reports of Progress of Chemistry	100 0 0			
Metrical Committee	25 0 0			
Zoological Record	100 0 0			
Committee on Thermal Equivalents of the Oxides of Chlorine	10 0 0			
„ Tidal Observations	100 0 0			
„ Fossil Flora	25 0 0			
„ Luminous Meteors	30 0 0			
„ British Fossil Corals	25 0 0			
„ Heat in the Blood	7 2 6			
„ British Rainfall	50 0 0			
„ Kent's Hole Explorations	150 0 0			
„ Fossil Crustacea	25 0 0			
„ Methyl Compounds	25 0 0			
„ Lunar Objects	20 0 0			
„ Fossil Corals Sections, for Photographing	20 0 0			
„ Bagshot Leaf-Beds	20 0 0			
„ Moab Explorations	100 0 0			
„ Gaussian Constants	40 0 0			
		1472	2	6
„ Committee on Treatment and Utilization of Sewage		800	0	0
„ Stock purchased, £500 3 per cent. Consols		464	7	6
		4266	14	4
1871. Aug. 2. Balance at London and Westminster Bank	£561 17 5			
„ at Messrs. Robarts, Lubbock & Co.	401 9 3			
„ in hands of General Treasurer	9 3 11			
		972	10	7
		£5239	4	11

W. SPOTTISWOODE,
August 2, 1871.

OFFICERS AND COUNCIL, 1871-72.

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WILLIAM HENRY HALLETT, Esq., F.L.S.

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Report of the Council for the Year 1870–71, *presented to the General Committee at Edinburgh, on Wednesday, August 2nd,* 1871.

At each of their meetings during the past year the Council have as usual received a report from the General Treasurer, as well as one from the Kew Committee. A *résumé* of these Reports will be laid before the General Committee this day.

The Council have had under their consideration the several resolutions, five in number, referred to them by the General Committee at Liverpool. They beg to report as follows upon the action they have taken in each case:—

First Resolution—"That the discontinuance of the maintenance of Kew Observatory by the British Association having been determined on, the President and Council be authorized to communicate with the President and Council of the Royal Society, and with the Government, so that the future use of the buildings may in 1872 be placed at the disposal of the Royal Society, in case the Royal Society should desire it, under the same conditions as those buildings are at present held by the British Association."

A copy of this resolution was forwarded by direction of your Council to the President and Council of the Royal Society. The following is the reply which one of your General Secretaries has received from Dr. Sharpey, Secretary of the Royal Society:—

"The Royal Society, Burlington House,
July 8, 1871.

"Dear Dr. Hirst,—In reply to your letter of the 10th December, 1870, enclosing a copy of a resolution of the General Committee of the British Association relative to the future occupation of the buildings at Kew now held by the British Association, I am directed to acquaint you that the President and Council of the Royal Society are ready to take possession of the Observatory at Kew on the terms it is at present held from Her Majesty's Government, as stated in a letter dated 26th March 1842, addressed to the President of the British Association from the Office of Woods, &c., viz.:— 'during the pleasure and upon the conditions usual on such occasions, that no walls shall be broken through, and no alterations made that can affect the stability of the building, and alter its external appearance, without the previous sanction of the Board of Works.' I have further to acquaint you that the President and Council have appointed a Standing Committee of Fellows of the Royal Society for the management of the Kew Observatory in accordance with the terms of the Gassiot Trust, consisting of the following gentlemen:—

Mr. Warren De La Rue.
Mr. Francis Galton.
Mr. Gassiot.
Admiral Richards.
Sir Edward Sabine.
Colonel Smythe.
Mr. Spottiswoode.
Sir Charles Wheatstone:

and that £600 from the income of the Gassiot Fund has been placed at the disposal of that Committee to meet the expenses of the establishment for the ensuing year.

"I remain, yours very truly,
(Signed) "W. Sharpey, M.D., *Secretary R. S.*"

Through the munificence of Mr. Gassiot, therefore, the Association can, without detriment to science, give up possession of the Kew Observatory at once instead of in 1872, as was originally contemplated. Your Council accordingly recommend that Government should be informed without further delay of the desire of the Association to see the direction and maintenance of the Kew Observatory transferred to the Royal Society.

Second Resolution.—"That the Council be empowered to cooperate with the Royal and Royal Astronomical Societies, in the event of a new application being made to Government to aid in the observation of the Solar Eclipse of December 1870."

On the 4th November a Joint Committee of the Royal and Royal Astronomical Societies decided to make a second application; on the 5th of November your Council selected a few of their body to accompany the new deputation to Government which the above two Societies had resolved to send. The necessity for any such deputation was subsequently obviated through the intervention of private individuals, and, as is well known, aid was promptly and liberally granted by Government to the Eclipse Expedition.

Third Resolution.—"That the Council be requested to take such steps as they deem wisest, in order to urge upon Government the importance of introducing scientific instruction into the elementary schools throughout the country."

A Committee of your Council having considered the subject, recommended the appointment of a deputation to wait upon the Lord President of the Council in order to urge upon him the desirability of including elementary natural science amongst the subjects for which payments are made by the authority of the Revised Code. The Council accordingly formed themselves into a deputation, and on the 13th of December 1870 had an interview with the Right Hon. W. E. Forster, M.P., Vice-President of the Committee of Council on Education, who was pleased to express his concurrence with the objects of the deputation and his willingness to carry out those objects so far as circumstances would permit.

Fourth Resolution.—"That the Council of the British Association be authorized, if it should appear to be desirable, to urge upon Her Majesty's Government the expediency of proposing to the legislature a measure to insure the introduction of the metric system of weights and measures for international purposes."

The Council deemed it expedient to postpone the consideration of this resolution.

Fifth Resolution.—"That it is inexpedient that new institutions, such as the proposed Engineering College for India, should be established by Government, until the Royal Commission now holding an inquiry into the relation of the State to scientific instruction shall have issued their report. That the Council of the British Association be requested to consider this opinion, and, should they see fit, to urge it upon the attention of Her Majesty's Government."

The Committee appointed without loss of time to consider and report on this resolution were informed at their first meeting that the arrangements for the establishment of the College had been virtually completed. Your President, however, in accordance with the wishes of this Committee, entered into unofficial communication with the authorities at the India Office, relative to the proposed examination for entrance into the new Engineering College, and succeeded thereby in gaining for natural science, as compared with

classics, a recognition, in the form of allotted marks, which it previously did not possess.

Your Council has given considerable attention to the important question (raised at the last meeting) of a revision of the regulations relating to the proceedings of the several Sections at the annual meetings of the Association. Hitherto, it has been justly urged, these proceedings, from not having been sufficiently pre-arranged, have frequently been of too desultory and mixed a character. It is hoped that by a proper observance of the Revised Regulations which are this day to be submitted to the General Committee for approval, and by increased vigilance on the part of the Sectional Committees, much of this may be obviated, and that greater prominence may be given to, and a fuller discussion secured for, the really important communications which are annually made to the several Sections.

The Council has pleasure in informing the General Committee that the Association at length possesses a central office in London. The Asiatic Society has, in consideration of a yearly rent of £100, granted to the Association entire possession of four of their rooms at 22 Albemarle Street, and the use of another room for meetings of the Council and Committees. Your Council, moreover, acting under the power given to them by the General Committee at Liverpool, have engaged Mr. Askham as clerk at a salary of £120 a year. He is in attendance daily, and there transacts much of the business which was formerly done at the office of Messrs. Taylor and Francis, the printers to the Association. With the exception of certain works of reference, the whole of the books and MSS. formerly deposited at Kew have been transferred to 22 Albemarle Street, and are being catalogued and rendered available for reference by Members of the Association. One of the four rooms not at present in use has been sub-let to the London Mathematical Society.

The Council having been informed by Dr. Hirst of his desire at the close of the present Meeting to resign his office as Joint General Secretary of the Association, appointed a Committee, consisting of the General Officers and former General Secretaries, to select a successor. This Committee unanimously recommended the appointment of Captain Douglas Galton, C.B., F.R.S. The Council, entirely agreeing with the Committee as to the high qualifications of Captain Galton for the office, cordially recommend his election by the General Committee at their meeting on Monday next.

The Council cannot allow this occasion to pass without expressing their sense of the great services rendered to the Association by Dr. Hirst; but they abstain from saying more, as they are unwilling to anticipate a more mature expression on the part of the General Committee.

The Council have added the following names of gentlemen present at the last Meeting of the Association to the list of Corresponding Members:—

Professor Van Beneden.
Dr. Crafts.
Dr. Anton Dohrn.
Governor Gilpin, Colorado.
H. H. the Rajah of Kolapore.
M. Plateau.
Professor Tchebichef.

The General Committee will remember that Brighton has already been selected as the place of meeting next year. Invitations for subsequent meetings have been received by your Council from Bradford, Belfast, and Glasgow.

The Council, lastly, recommend that the name of Professor Balfour be added to the list of Vice-Presidents of the present Meeting.

Report of the Kew Committee of the British Association for the Advancement of Science for 1870–71.

The Committee of the Kew Observatory submit to the Council of the British Association the following statement of their proceedings during the past year:—

(A) Work done by Kew Observatory under the direction of the British Association.

1. *Magnetic work.*—In their last Report the Committee stated the plan on which they proposed to reduce their Magnetic observations; they now report that with reference to the reduction of the Magnetic Disturbances from January 1865 to December 1869, the period following that which has already been published, the discussion of Declination and Horizontal Force Disturbances is nearly ready for presentation to the Royal Society, and that of the Vertical Force is in progress; when that is completed, the whole period, 1865 to 1869 inclusive, will have been discussed at Kew. The tabular statement, which is herewith presented (see Appendix I.), exhibits the exact state of the reduction.

Two Dipping-needles by Dover and one by Adie have been tested for Mr. Chambers, Superintendent of the Colaba Observatory; and one needle has been procured from Dover and tested for Prof. Jelinek, of Vienna.

A Dip-circle by Dover has been verified and forwarded to Prof. Jelinek, who ordered it on behalf of the K. K. militär-geographisches Institut.

Major-General Lefroy, Governor of Bermuda, having applied for the loan of a Dip-circle, one has now been prepared for his use, and will be forwarded to Bermuda as soon as possible. A Dip-circle has been obtained from Dover, and, after verification, will be forwarded to the Survey Department, Lisbon.

At the request of Prof. Jelinek the Committee have undertaken to examine a Dip-circle by Repsold. It is of a large size and has eight needles, but Prof. Jelinek reports that the results obtained by them are very discordant.

Copies of certain specified magnetograph curves have been made and forwarded to the late Sir J. Herschel, M. Diamilla Müller, of Florence, and Senhor Capello, of Lisbon, at the request of those gentlemen.

The usual monthly absolute determinations of the magnetic elements continue to be made by Mr. Whipple, the Magnetic Assistant.

The Self-recording Magnetographs are in constant operation as heretofore, also under his charge.

2. *Meteorological work.*—The meteorological work of the Observatory continues in the charge of Mr. Baker.

Since the Liverpool Meeting, 113 Barometers (including 17 Aneroids) have been verified, and 2 rejected; 1320 Thermometers and 215 Hydrometers have likewise been verified.

Two Standard Thermometers have been constructed for Owens College, Manchester, one for the Rugby School, one each for Profs. Harkness and Eastmann, of the Washington Observatory, four for Dr. Draper, of the New York Central Park Observatory, one for Major Norton, of the Chief Signal Office, Washington, one for Mr. G. J. Symons, and three for the Meteorological Committee.

Three Thermograph Thermometers have been examined for Mr. Chambers, of the Colaba Observatory, and three for the Meteorological Committee.

Two Standard Barometers have been purchased from Adie, and tested at Kew, one of which has been forwarded to the Chief Signal Office, Washington, and the other to Prof. Jack, of Fredricton, New Brunswick.

Tubes for the construction of a Welsh's Standard Barometer on the Kew pattern, together with the necessary metal mountings, and a Cathetometer, have been made under the superintendence of the Committee for the Chief Signal Office, Washington.

The Committee have likewise superintended the purchase of meteorological instruments for Owens College, Manchester, and for the Observatory attached to the University of Fredricton, New Brunswick.

The Kew Standard Thermometer (M. S. A.), divided arbitrarily by the late Mr. Welsh, and employed for many years past as the standard of reference in the testing of thermometers, was accidentally broken on the 3rd of January. Since then a Kew Standard, of the ordinary construction, made in 1866, and which had been compared on several occasions with M. S. A., has been used to replace it.

Copies of some of the meteorological observations made at Kew during the years 1869 and 1870 have been supplied to the Institution of Mining Engineers at Newcastle-upon-Tyne, and the Editor of Whitaker's Almanac, the cost of the extraction being paid by the applicants in both instances.

A set of self-recording meteorological instruments, the property of the Meteorological Committee, have been erected in the Verification-house, and are now undergoing examination.

The self-recording metereological instruments now in work at Kew will be again mentioned in the second division of this Report. These are in the charge of Mr. Baker.

3. *Photoheliograph.*—The Kew Heliograph, in charge of Mr. Warren De La Rue, continues to be worked in a satisfactory manner. During the past year 362 pictures have been taken on 205 days. The prints from the negatives alluded to in last Report have been taken to date, and the printing of these has become part of the current work of the establishment. A paper by Messrs. Warren De La Rue, Stewart, and Loewy, embodying the position and areas of sun-groups observed at Kew during the years 1864, 1865, and 1866, as well as fortnightly values of the spotted solar area from 1832 to 1868, has been published in the Philosophical Transactions, and distributed to those interested in solar research. A Table exhibiting the number of sun-spots recorded at Kew during the year 1870, after the manner of Hofrath Schwabe, has been communicated to the Astronomical Society, and published in their 'Monthly Notices.'

An apparatus is being constructed under the direction and at the expense of Mr. Warren De La Rue, and it will shortly be erected on the Pagoda in Kew Gardens, in order to be employed in obtaining corrections for optical distortion in the heliographical measurements.

4. *Miscellaneous work.*—Experiments are being made on the heat produced by the rotation of a disk *in vacuo.*

A daily observation has been made with the Rigid Spectroscope, the property of Mr. J. P. Gassiot.

Observations have been made with two of Hodgkinson's Actinometers, the property of the Royal Society, in order to compare them with the Actinometers deposited at the Observatory, for reference, before forwarding them to India.

The Committee have superintended the purchase of optical apparatus, chemicals, &c. for the Observatories at Coimbra and Lisbon.

An inventory has been made of the apparatus, instruments, &c. at present deposited in the Observatory, and forms Appendix III. of the present Report.

In Appendix II. a list is given of the books at present in the Observatory, the property of the British Association.

List B (Appendix II.) is a rough inventory of books, the property of the British Association, which have been transferred from the Observatory to the rooms of the Association in London for the purpose of being catalogued.

(B) Work done at Kew as the Central Observatory of the Meteorological Committee.

1. *Work done at Kew as one of the Observatories of the Meteorological Committee.*—The Barograph, Thermograph, Anemograph, and Rain-gauge are kept in constant operation. Mr. Baker is in charge of these instruments.

From the first two instruments traces in duplicate are obtained, one set being sent to the Meteorological Office and one retained at Kew. As regards the Anemograph and Rain-gauge, the original records are sent, while a copy by hand of these on tracing-paper is retained. The tabulations from the curves of the Kew instruments are made by Messrs. Page and Rigby.

2. *Verification of Records.*—The system of checks devised by the Kew Committee for testing the accuracy of the observations made at the different Observatories continues to be followed, as well as the ruling of zero lines in the Barograms and Thermograms suggested by the Meteorological Office. Messrs. Rigby and Page perform this work, Mr. Baker, Meteorological Assistant, having the general superintendence of the department.

3. *Occasional Assistance.*—The Meteorological Committee have availed themselves of the permission to have the occasional services of Mr. Beckley, Mechanical Assistant at Kew; and he has lately been visiting the various Observatories of the Meteorological Committee.

The self-recording Rain-gauge, as mentioned in the last Report, has been adopted by the Meteorological Committee, and instruments of this kind have been constructed for the various Observatories.

A series of comparative observations was commenced in April 1870 of two Anemometers erected in the grounds attached to the Observatory, in order to compare the indications of a large and small instrument; but as a discussion of the result showed them to have been greatly affected by the influence of the neighbouring buildings, the instruments were dismounted in January last and re-erected in an open part of the Park, at a distance from the Observatory. Three months' observations were made in this position, and as these proved satisfactory, the instruments have been dismounted. The cost of this experiment has been defrayed by the Meteorological Committee. Owing to his duties in Manchester, and to a railway accident, Dr. Stewart has not been able during the last year to devote much time to the Observatory. During his absence his most pressing duties were discharged by Mr. Whipple in an efficient manner.

The Observatory was honoured on the 9th of July by a visit from the Emperor and Empress of Brazil. Their Majesties were received, on behalf of the Committee, by Sir E. Sabine and Mr. W. De La Rue.

In the unavoidable absence, through illness, of Dr. Balfour Stewart, the Emperor was conducted over the Observatory by the above-named gentlemen, and the various instruments &c. were explained by Mr. Whipple and the other members of the staff of the Observatory.

APPENDIX I.

Tabular statement showing state of Magnetic Reductions at the present date.

	Hourly Tabulations from Traces.		Correct Monthly Means.	Disturbances excluded and aggregated.	Lunar Diurnal Variation Tables.	Tables of Secular and Annual Variation.	Solar Diurnal Variation Tables.
	By Tabulator.	By Subsidiary Scale.					
Declination.	1865	1865	1865	1865	1865	1865	1865
	1866	1866	1866	1866	1866	1866	1866
	1867	1867	1867	1867	1867	1867	1867
	1868	1868	1868	1868	1868	1868	1868
	1869	1869	1869	1869	1869	1869	1869
	1870	1870*	......	......	......	......	......
Horizontal Force.	1865	1865	1865	1865	......	1865	......
	1866	1866	1866	1866	......	1866	......
	1867	1867	1867	1867	......	1867	......
	1868	1868	1868	1868	.....	1868	......
	1869	1869	1869	1869	......	1869	......
	1870	1870*	......	......	......	......	......
Vertical Force.	1865	1865	......	......	......	1865	......
	1866	1866	......	......	......	1866	......
	1867	1867	......	......	......	1867	......
	1868	1868	......	......	......	1868	......
	1869	1869	......	......	......	1869	......
	1870	1870*	......	......	......	......	......

* The reduction of the tabulations for the year 1870 is being performed in Sir E. Sabine's office.

Arrears of Work.

	Hourly Tabulations from Traces.		Correct Monthly Means.	Disturbances excluded and aggregated.	Lunar Diurnal Variation Tables.	Tables of Secular and Annual Variation.	Solar Diurnal Variation Tables.
	By Tabulator.	By Subsidiary Scale.					
Declination.	1858	1858	1858	1858	1858†	1858†	1858†
	1859	1859	1859	1859	1859†	1859†	1859†
	1860	1860	1860	1860	1860†	1860†	1860†
	1861	1861	1861	1861	1861†	1861†	1861†
	1862	1862	1862	1862	1862†	1862†	1862†
	1863	1863	1863	1863	......	......	......
	1864	1864	1864	1864	......	......	......
Horizontal Force.	1858	1858	1858	......	......	1858	......
	1859	1859	......	......	......	1859	......
	1860	1860	......	......	......	1860	......
	1861	1861	1861	......	......	1861	......
	1862	1862	1862	......	......	1862	......
	1863	1863	1863	1863	......	1863	......
	1864	1864	1864	1864	......	1864	......
Vertical Force.	1858	......	......	......	......	1858	......
	1859	......	......	......	......	1859	......
	1860	1860	......	......	......	1860	......
	1861	1861	......	......	......	1861	......
	1862	1862	......	......	......	1862	......
	1863	1863	......	......	......	1863	......
	1864	1864	......	......	......	1864	......

† These have been already published by Sir E. Sabine.

APPENDIX II.

BOOKS AT PRESENT IN THE KEW OBSERVATORY,

THE PROPERTY OF

THE BRITISH ASSOCIATION.

LIST A.

Books to be retained at Kew for reference.

British Association Reports, 1 vol. for the following years:—
1831–32, 1833, 1834, 1835, 1836, 1837, 1838, 1839, 1840, 1841, 1842, 1843, 1844, 1845, 1846, 1847, 1848, 1849, 1850, 1851, 1852, 1853, 1854, 1855, 1856, 1857, 1858, 1859, 1860, 1861, 1862, 1863, 1864, 1865, 1866, 1867, 1868, 1869.

Philosophical Transactions	88 vols.
" " (Abstracts)	6 "
Proceedings of the Royal Society	12 "
Royal Society Catalogue of Scientific Papers	4 "
Philosophical Magazine (half-yearly)	21 "
" " (unbound)	11 parts.
Logarithmic Tables (various)	6 vols.
Royal Astronomical Society's Proceedings	13 "
Buchan's Meteorology	2 "
Dalton's "	1 "
Kaemtz's "	1 "
Meteorological Papers	27 nos.
Meteorology of England	18 nos.
Papers relating to the Meteorological Department of the Board of Trade	39 "
Instructions for taking Meteorological Observations (Col. James)	1 vol.
Quarterly Weather Reports	3 vols.
British Almanac	2 "
Deviations of the Compass (Evans)	2 "

Miller's Elements of Chemistry	2 vols.
Williamson's Chemistry for Students	1 vol.
Elements of Chemistry (Sir R. Kane)	1 „
Mathematics (Royal Military Academy Course)	2 vols.
Euler's Letters on Mathematics and Physics	4 „
Barlow on Magnetic Attraction	1 vol.
Treatise on Electricity (De La Rive)	3 vols.
Woodhouse's Astronomy	1 vol.
The Heavens (Guillemin, edited by Norman Lockyer)	1 „
Art of Photography (Lake Price)	1 „
Meteorological Tables, Smithsonian (Guyot)	1 „
Treatise on Mathematical Instruments (Heather)	1 „
Sabine's Pendulum and other Experiments	2 vols.
Chauvenet's Astronomy	2 „
Timbs's Year-Book of Facts, 1861–1871	11 „
Taylor's Scientific Memoirs	2 „
Manual of Surveying for India, by Capts. Smythe and Thuillier	1 vol.
Nichol's Cyclopædia of Physical Science	1 „
Admiralty Manual of Scientific Enquiry	1 „
Dictionary of Terms of Art (Weale)	1 „
Magnetic and Meteorological Observations at :—	
St. Helena	3 vols.
Toronto	5 „
Hobarton	5 „
Cape of Good Hope	1 vol.
Observations during Magnetic Disturbances, 1840–1841	1 „
Magnetic and Meteorological Observations, Unusual Disturbances	1 „
Plates to Magnetic and Meteorological Observations	1 „
Report of the Astronomer Royal to the Board of Visitors	40 nos.
Theory of Errors of Observations, by Airy	1 vol.
Todhunter's Conic Sections	1 „
Distribution of Heat (Dove)	1 „
Optics (Potter)	1 „
Camus on the Teeth of Wheels	1 „
Simmonds's Meteorological Tables	1 „
Observations of Sun-spots (Carrington)	1 „
Newton's Principia	1 „
Symons's British Rainfall and Meteorological Magazine	
Expériences sur les Machines à Vapeur (Regnault)	2 „
Cours Elémentaire de Chimie (Regnault)	4 „

LIST B.

Books to be sent to the London Office, 22 Albemarle Street.

British Association Report,		1831–32	20 vols.
”	”	1833	20 ”
”	”	1834	20 ”
”	”	1835	20 ”
”	”	1836	20 ”
”	”	1837	20 ”
”	”	1838	20 ”
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”	”	1865	22 ”
”	”	1866	22 ”
”	”	1867	22 ”
”	”	1868	22 ”
”	”	1869	22 ”
Lalande's Catalogue (MS. Calculations)			96 ”
” ” (MS. copy)			3 ”
La Place's Celestial Mechanics			1 vol.
Armagh, Places of Stars			1 ”
Radcliffe Observatory Catalogue of Stars for 1845			1 ”
Paramatta Catalogue of 7358 Stars			1 ”
Groombridge's Catalogue of Circumpolar Stars			3 vols.
Edinburgh Astronomical Observations			4 ”
Astronomical Observations at the Cape of Good Hope			1 ”

(MSS.) Apparent Places of Principal Stars	1	vol.
British Association Catalogue (MS. copy)	1	,,
(MSS.) British Association Catalogue (Calculations)	24	vols.
(MSS.) British Association Catalogues, Synonyms and Notes	23	,,
(MSS.) Lacaille's Catalogue (Calculations)	24	,,
Lacaille's Catalogue (MS. copy)	1	,,
Proceedings of the Royal Institution of Great Britain	33	nos.
Ordnance Survey, Comparisons of Standards of Length	2	vols.
Radcliffe Observatory, Meteorological Observations	3	,,
Makerstoun, Meteorological Observations and Tables	10	,,
,, Abstracts of Meteorological Observations	3	,,
Cambridge Observations	8	,,
Playfair's Natural Philosophy	2	,,
Bland's Algebraical Problems	1	,,
Lectures on Quaternions (Sir W. Hamilton)	1	,,
Meteorological and Nautical Observations at Melbourne and Victoria	1	,,
Mastery of Languages (Prendergast)	1	,,
La Place's Analytical Mechanics	1	,,
Levelling in England and Wales	1	,,
,, ,, (Abstract)	1	,,
Levelling in Scotland	1	,,
,, ,, (Abstract)	1	,,
Pasley on Measures, Weights, and Money	1	,,
Cork Savings-bank Tables	1	,,
Weld's History of the Royal Society	2	,,
Bombay Magnetical and Meteorological Observations, 1845	3	,,
Meteorological Results, Toronto	8	,,
Greenwich Observations	52	,,
,, ,, (Appendices &c.)	125	,,
Catalogue of Reference, Manchester Free Library	1	,,
Brisbane's Star Catalogue	2	,,
Johnson and Henderson's Star Catalogue	2	,,
(MSS.) Hartnup Star Catalogue	1	,,
Mayer's Star Catalogue	1	,,
Wrottesley's Star Catalogue	1	,,
Taylor's ,, ,,	8	,,
Everest's Survey of India	2	,,
Ordnance Survey	6	,,
Extension of Triangulation into Belgium and France	2	,,
Verification and Extension of Lacaille's Arc of Meridian	2	,,
Schlagintweit's India and High Asia	2	,,
Proceedings of Institution of Mechanical Engineers	8	,,
,, ,, ,, ,,	70	nos.
Modern Geology Exposed	1	vol.
Melbourne Magnetic and Meteorological Observations	3	vols.
Extracts from the Great Trigonometrical Survey of India	5	,,
Madras Meteorological Observations	2	,,
Sydney ,, ,,	38	nos.
Calcutta Hourly Meteorological Observations	7	,,
Bengal Meteorological Reports	5	,,

Statistics of New Zealand	9 nos.
Tide Tables for English and Irish Ports	7 ,,
Reports and Transactions of the Devonshire As ociation	3 vols.
Annual Reports of the Royal Polytechnic Society	17 ,,
Transactions of the Historic Society of Lancashire and Cheshire	17 ,,
Transactions of the Royal Scottish Society of Arts	10 ,,
Results of Trials on H.M. Ships	5 ,,
Trigonometrical Survey of England and Wales	3 ,,
Determination of Longitudes of England and Wales	2 ,,
La Place's Mathematical Works	6 ,,
Lagrange's ,, ,,	6 ,,
Euler's Mathematical Works	4 ,,
Simpson's ,, ,,	2 ,,
Dupin's ,, ,,	1 vol.
Carnot's ,, ,,	1 ,,
Shipbuilding, by Rankine	1 ,,
Dublin Magnetical and Meteorological Observations	1 ,,
Maxima and Minima (Ramchundra)	1 ,,
Meteorological Results Toronto, 1862	1 ,,
Army Meteorological Register	1 ,,
Mathematical Tracts from Library of the late Mr. Christie	
Magnetical and Meteorological Observations at Lake Athabasca.	
Sundries (English Pamphlets).	
U. S. Coasts Survey, Report of Superintendent	25 vols.
Annals of the Dudley Observatory	4 ,,
Transactions of the Albany Institute	5 ,,
Proceedings of the American Geological and Statistical Society	10 ,,
Reports of the National Academy of Sciences	5 ,,
Documents of the U. S. Sanitary Commission	5 ,,
State Transactions of the Historic Society of Wisconsin	6 ,,
Report of Geological Reconnaisance of Arkansas	2 ,,
Proceedings of the Boston Society of Natural History	45 ,,
,, of the American Association for the Advancement of Science	12 ,,
Monthly Report of the Commissioners of the Revenue of U. S. A.	5 ,,
Proceedings of the American Academy of Arts and Sciences	20 ,,
Proceedings of the American Philosophical Society	50 ,,
Papers relating to Harvard College	60 ,,
Proceedings of the Academy of Natural Sciences, Philadelphia	71 ,,
Smithsonian Miscellaneous Collections	20 ,,
,, Contributions to Knowledge	26 ,,
Memoirs of the American Academy	9 ,,
Washington Astronomical and Meteorological Observations	9 ,,
Maury's Sailing Directions	3 ,,
Transactions of the American Philosophical Society	6 ,,

Sundry Volumes (various subjects)	16	vols.
Smithsonian Reports	22	,,
Explorations and Surveys, Senate, U. S. A.	4	,,
Reports of the Department of Agriculture, U. S. A.	8	,,
Geology of Iowa	2	,,
Catalogue, Army Medical Museum, U. S. A.	1	,,
Sundries, (American Pamphlets.)		
Bulletin de la Société de Géographie	42	,,
,, ,, ,,	34	nos.
Mémoires de l'Académie de Dijon	13	vols.
Bulletin de la Fédération de la Société de Horticulture de Belgique	9	,,
Actes de la Société Helvétique	7	,,
Mémoires de l'Académie Royale de Metz	3	,,
Résumé Météorologique pour Genève and Le Grand St. Bernard	6	,,
Extraits de l'Académie Royale de Bruxelles	10	nos.
Bulletin de la Société Vaudoise	4	,,
Mémoires de la Société des Sciences	7	,,
Revues des Cours Scientifiques	19	,,
Panhellenium	20	,,
Quetelet sur le Climat de la Belgique	7	,,
Extraits de l'Académie de Belgique	54	,,
Commission Hydrométrique de Lyon	16	,,
Bulletin de l'Association Scientifique de France	140	,,
Mémoires de l'Académie des Sciences et Lettres de Montpellier	5	,,
Atlas Météorologique de l'Observatoire Impérial, 1866–1869	4	,,
La Belgique Horticole	6	,,
Compte Rendu Annuel	15	vols.
Annales de l'Observatoire Physique Central (Russia)	35	,,
Annuaire Magnétique et Météorologique (Russia)	4	,,
Annuaire Météorologique de France	7	,,
Cosmos	4	,,
Les Mondes, 1863–70.	8	,,
Tables de la Lune, par Hanseen	1	vol.
Traité de Calcul Différential, par Lubbe	1	,,
Histoire Céleste, par Lalande	1	no.
Sundries. (French Pamphlets.)		
Oversigt over det K. D. V. Selskabs af Forchhammer	33	,,
Videnskabernes Selskabs Skrifter	6	vols.
Sundries. (Dutch Pamphlets.)		
Archives Neerlandaises.		
Meteorologische Waarnerningen	30	,,
Helsingfors Magnetical and Meteorological Observations	6	,,
Acta Societatis Scientiarum Fennicæ	8	,,
,, ,, Indo-Neerlandsch	7	,,
Norsk Meteorologisk Aarbog	4	,,
Meteorologische Jagttagelser paa Christiania Observatorium	6	,,

Meteorologische Beobachtungen Aufgezeichnet auf Christiania Observatorium	3	vols.
Beretning om en Botanisk Reise af H. L. Lorensen	6	„
Index Scholarum in Universitate Christiania	18	„
Sundries. (Norwegian Pamphlets.)		
Sitzungsberichte der Mathematisch Naturwissenschaftliche Classe der Akademie der Wissenschaften	280	„
Sitzungsberichte der K. B. Akademie der Wissenschaften	78	„
Mittheilungen der Naturforschenden Gesellschaft in Bern	11	„
Monatsberichte der K. P. Akademie der Wissenschaften zu Berlin	80	„
Annalen für Meteorologie und Erdmagnetismus	6	„
Beobachtungen Meteorologische an der Wiener Sternwarte	22	„
Verhandlungen der Allgemeinen Schweizerischen Gesellschaft der Naturwissenschaften	16	„
Zeitschrift der Osterreichischen Gesellschaft für Meteorologie	130	„
Reise der Osterreichischen Frigatte Novara, Magnetische Beobachtungen	3	„
Magnetische Beobachtungen in Wien	4	„
Tageblatt der 32 Versammlung der N. W. A. in Wien, 1856	9	„
Jahrbucher der K.-K. Central Anstalt für Meteorologie und Erdmagnetismus in Wien. 1856–1859, 1 of each, 1866–1869, 2 of each	10	nos.
Det Kongelige Norske Universitets Aarberetunger, 1856 to 1858	8	vols.
Travaux de la Commission pour fixer les mesures et les poids de l'Empire de Russie	3	„
Abhandlungen der Math-Physikal Classe der K. B. Akademie der Wissenschaften	4	„
Bulletin der Akademie der Wissenschaften der München.	47	„
Sundries. (German Pamphlets.)		
Annaes do Observatorio do Infante D. Luiz	46	„
Trabalhos „ „	5	„
Mémoires de Académie Reale de Sciences de Lisboa	8	„
Annaes da Academia das Sciencias Lisboa	12	„
Coimbra, Observacoes Meteorologicas	21	„
Sundries. (Portuguese Pamphlets.)		
Russian Nautical Magazine	63	„
Harmonia Mensuram.		
Ædes Hartwellianæ	1	vol.
Speculum Hartwellianum	1	„
Diverse Machine (Ramelli)	1	„
Memorie dell' I. R. Istituto Lombardo	5	vols.
Memorie della Società Italiana delle Scienze	5	„
Memorie dell' Osservatorio del Collegio Romano	10	„
Memorie del Reale Istituto Lombardo	41	„
Atti dell' Accademia Pontificia de' Nuovi Lincei	90	„
Atti del Reale Istituto Lombardo	29	„

Atti della Reale Accademia delle Scienze di Napoli......	7 vols.
Bulletino Meteorologico dell' Osservatorio del Collegio Romano..........	9 ,,
Giornale dell' I. R. Istituto Lombardo................	44 ,,
Rendiconti del Reale Istituto Lombardo..............	112 ,,
Sundries. (Italian Pamphlets.)	

APPENDIX III.

Inventory of Apparatus and Instruments at present in the Kew Observatory, with the names of Owners or Funds by which they were purchased. May 1871.

[Abbreviations adopted in col. 2:—Brit. Assoc. for British Association; Don. Fund for Donation Fund; Gov. Grant for Government Grant Fund; Met. Com. for Meteorological Committee; Par. Ex. Fund for Paris Exhibition Fund; Roy. Ast. Soc. for Royal Astronomical Society; Royal Soc. for Royal Society.]

Entrance Hall.	Property of, or Purchased by,
Bird's Mercurial Thermometer	Royal Soc.
Captain Kater's Hygrometer, by Robinson	,,
Dr. Lind's Portable Wind Gauge	,,
Huygens's Aerial Telescope (twelve parts)........	,,
Huygens's Object-glass	,,
Huygens's Object-glass, with two Eye-glasses by Scarlet	,,
Flamsteed's Object-glass (Venetian)	,,
Dollond's 42-inch Transit, with a cast-iron stand ..	,,
Short's 36-inch Reflecting Telescope, with an Object-glass Micrometer by Dollond (nine parts)	,,
Kater's Convertible Pendulum, with the Agate Planes	,,
Captain Sabine's Cylindrical Pendulum, vibrating on Planes; with the Knife-edges................	,,
Apparatus, with Leaden Balls, by Paull of Geneva (ten parts)	,,
Nairne and Blunt's 12-inch Dipping Needle (two parts)	,,
A 12-inch Variation Needle....................	,,
Dr. Godwin Knight's Battery of Magnets	,,
Air-Pump, with Double Barrel	,,
Nairne's Air Condenser (three parts)	,,
Ramsden's Great Theodolite, with other Instruments and Apparatus employed by Major-General Roy in the Trigonometrical Survey (sixty-six parts, in four cases), incomplete	,,

Cary's Large Levelling Instrument (twenty-one parts)	Royal Soc.
Troughton and Simms's Large Levelling Instrument (twenty parts)	"
Adams's 5-inch Theodolite (two parts)	"
Bowles's Trigonometer (four parts)	"
Troughton's Repeating Circle, of 1 foot diameter ..	"
Ramsden's 10-inch Protractor, with Vernier to 1′ ..	"
Bird's 12-inch Astronomical Quadrant (fifteen parts)	"
Fordyce's Hydrometer	"
Cole's Orrery, explanatory of Eclipses	"
Two Miner's Compasses	"
Armed Loadstone	"
Le Cerf's Brass Instrument	"
Curious Steel Callipers for very accurate measurement, by Paull of Geneva: 1777	"
Rowning's Universal Constructor of Equations	"
Chronometer Stove, for ascertaining the Influence of Temperature on the Rate of Chronometers (six parts)	"
Wedgewood's Pyrometer; or Thermometer for measuring high degrees of heat (sixty-six parts)	"
Two strong Brass Pulleys	"
Bird's 4-feet Refracting Telescope	"
Dicas's Hydrometer	"
Hadley's Metal for a Newtonian Reflector, with several wooden Eyepieces, but without Tube or Mounting	"
Troughton and Simms's 6-inch Circular Protractor ..	"
Baily's Pendulum, No. 2	Roy. Ast. Soc.
Standard Wrought-iron bar used in Mallet's Experiments, 1838–1842	Brit. Assoc.
Observing Telescope used by Schlagintweit.	
Experimental Tubes employed in the construction of Welsh's Standard Barometers	Gov. Grant.
Six 39-inch Glass Slabs.	
Sixty Lamp Chimneys	Brit. Assoc.
Eight 14-inch Magnets.	
Sundry Lamps, Plate Boxes, Daguerotypes and Apparatus employed with Ronalds's Self-recording Barograph and Magnetograph	Donat. Fund.
Sundry Chemical Apparatus used with Addams's Carbonic acid Gas Generators	Gov. Grant.
Three large Magnetometers with Marble Slabs, Pillars, Reading Telescopes, &c.	
Two Thermometer Testing-jars (damaged)	Brit. Assoc.
Two 6-inch Bull's-eye Lenses.	
Sir W. Thomson's Portable Atmospheric Electrometer	Prof. Sir W. Thomson.
Sir W. Thomson's Recording Atmospheric Electrometer	"
Various pieces of Electrical Apparatus	Sir F. Ronalds.
Sundry Lenses.	

Galton's Dial Anemometer, with Battery, &c.	Met. Com.
Artificial Horizon..........................	Sir E. Sabine.
Heliostats and Reflectors used in Mr. Galton's Sextant Testing Apparatus	Geogr. Soc.
Apparatus for Trisecting an Arc.	
Saussure's Hygrometer	SirF.Ronalds.
Seven-inch Protractor, by Jones.	
Marine Barometer.	
Two Patent Compensated Barometers, by Harris.	
One 30-inch Steel Bar.	
Two Kriel's Self-recording Barometers, with Spare Tubes	Brit. Assoc.
Tube of Ronalds's Photo-barograph	Gov. Grant.
Glass Receiver (damaged).	
Model of Sheerness Tide-gauge	Royal Soc.
Mallet's Model of the Descent of Glaciers.	
Several Models, not named.	
Appold's Automatic Hygrometer.................	Royal Soc.
Appold's Automatic Temperature Regulator	,,
Lindley's Patent Central Thermometer.	
Lindley's Model of Fire Escape.	
Perspective Instrument	SirF.Ronalds.
Barrow's Dip Circle, No.	Sir E. Sabine.
Robinson's 6-inch Circle	,,
Two Unifilars and a Declinometer, by Gibson......	,,
Seven Tripods	,,
Balance of Torsion.	
A Watchman's Clock.	
Oertling's Balance	Gov. Grant.
Two Aspirators	,,
Wooden Wind-pressure Gauge..................	,,
Altazimuth, by Cary	Sir E. Sabine.
Ronalds's Atmospheric Electrical Apparatus	Gov. Grant.
Model of Mr. De La Rue's Tower for supporting Huyghen's Aerial Telescope-lenses	Par.Ex.Fund.
Model of a design for Photoheliograph Mounting ..	Brit. Assoc.
Leyden Jars	Mr. Gassiot.

Testing Room.

Six frames exhibiting Kew and Lisbon Magnetic Curves	Brit. Assoc.
Two Welsh's Standard Barometers	Gov. Grant.
Cathetometer	,,
Receiver for testing Barometers, with Air-Pump, &c.	,,
Apparatus for testing Thermometers	,,
Newman's Standard Barometer, No. 34	,,
Brass Mural Quadrant........................	Observatory.
Spare Tubes for Standard Barometer construction ..	Gov. Grant.
Thomson's Galvanometer and Apparatus employed by Dr. Stewart in Rotating Disk experiments......	,,
Siemens's Air-Pump	,,
Sprengel's Air-Pump	,,

Parts of Ronalds's Magnetographs	Gov. Grant.
Air-Thermometer (incomplete)	,,
MSS., Books, Papers, Documents, and Correspondence referring to Meteorological work.	

Transit Room.

Thermometer-waxing Apparatus	Brit. Assoc.
Photographic Paper Waxing Apparatus	,,
Thomson's Atmospheric Recording Electrometer ..	Met. Com.
Thermograph	,,
Chronometer, Arnold	Gov. Grant.
Invariable Pendulum	Royal Soc.
Pendulum, No. 8	,,
Dip Circle, by Jordan	Sir E. Sabine.
Declinometer, by Robinson and Barrow	,,
Five Daniell's Hygrometers....................	,,
Four Declinometers (various makers)............	,,
Artificial Horizon	,,
Four Thermometers..........................	,,
Three Herschel's Actinometers	,,
10-inch Azimuth Compass	,,
Vertical Force Magnetometer	,,
Standard Yard..............................	,,
Three Dip Circles and one Fox's Circle	,,
Several old Observing Telescopes and incomplete Magnetic Apparatus..................	,,
Photographic Paper, waxed and unwaxed	Brit. Assoc.
Sundry Bottles, Chemicals, and Apparatus employed in the ordinary work of the Observatory	,,

Computing Room.

Dividing Engine by Perreaux, and Apparatus employed in the construction of Standard Thermometers	Gov. Grant.
Standard Thermometers, divided and undivided....	Brit. Assoc.
Evaporation Gauge (exhibited at Paris)	Par.Ex.Fund.
Portable Barometer, by Newman	Sir E. Sabine.
Gay-Lussac Barometer, by Bunter.	
Troughton and Simms's Mercurial Standard Thermometer	Royal Soc.
Newman's Spirit Thermometer for very low Temperatures	,,
Jones's Hygrometer.........................	,,
Set of Bar Magnets (six)......................	,,
Pair of Levelling Staves, by Jones	,,
Sundry old Thermometers.	
Thermometer, by Greiner	Sir E. Sabine.
Dry and Wet Thermometer, from Hobarton.	
Thermometer, No. 2, from Greenwich Observatory.	
Actinometer Tube	Rev. C. Hodgkinson.

Actinometer Tube	Royal Soc.
Two Actinometers	Rev. C. Hodgkinson.
Three Actinometers	Royal Soc.
Ten Hydrometers.	
Spirit-level used in Pendulum experiments	Gov. Grant.
Small Boiling-point Apparatus	Par.Ex.Fund.
Two Mountain Thermometers.	
One Regnault's Hygrometer	Gov. Grant.
One Daniell's Hygrometer.	
Several Declinometers, by various makers	Sir E. Sabine.
Several Unifilars, by various makers	"
Several Dip Circles, by various makers	"
Two Altazimuth Instruments	Admiralty.
Repeating Circle, by Dollond	Sir E. Sabine.
Vertical Force Magnetometer	"
Sundry Magnets, Dip Needles, Magnet Fittings, Inertia Bars, Rings, &c., belonging to various instruments	"
Magnets and Needles in use at the Observatory	"
Standard Yard	Gov. Grant.
Standard Weights	"
Jars and Standard Solutions used in Hydrometer-testing	Brit. Assoc.
Chemicals and Chemical Apparatus used in the Observatory	"
Apparatus employed by Prof. Clerk Maxwell.	
Telescope support, by Goloz	Royal Soc.
Several Tripods	"
Surveying Rods	"
6-inch Globe	"
Model of Hydraulic Anemometer	Mr. Galton.
Several Rules and Scales in use	Brit. Assoc.
Box of Ozonometer Papers.	
Magnetograph Curves	Brit. Assoc.
Magnetic Observation-books	"
MS. Papers of Magnetic Reductions	"
MS. Papers on various subjects	"
Surplus copies of Publications issued by Observatory	Roy. Soc. and Brit. Assoc.
Wood Engravings of Magnetograph Drawings	Brit. Assoc.

South Hall.

Cooke's Sextant Testing Apparatus	Gov. Grant.
Shelton's Astronomical Regulator, with Gridiron Pendulum	Royal Soc.
Gas Governors and Regulators	Don. Fund.

Magnetograph Room.

Magnetographs	Gov. Grant.
Earthenware Stove	Brit. Assoc.

Deflecting Apparatus	Brit. Assoc.
Barograph	Met. Com.
Rigid Spectroscope	Mr. Gassiot.

Pendulum Room.

Vacuum Chamber and Vibrating Apparatus	Admiralty.
Observing Telescope	"
Shelton's Astronomical Regulator	Royal Soc.

Transit House.

Portable Transit Instrument	Sir E. Sabine.
Apparatus for determining Scale value of Levels	Mr. Adie.

Lower Photographic Room.

Baths, Dishes, Bottles, and Chemical Apparatus	Gov. Grant.
Chemicals and Paper	Brit. Assoc.
Printing Frames	"

Meteorological Room.

Globe	Brit. Assoc.
Barograph, Thermograph, and Anemograph Curves	Met. Com.
Ditto (duplicates)	Brit. Assoc.
Tabulations of ditto (duplicates).	
Scales, Rules, &c., employed in tabulating Curves	Met. Com.
Post Cases, MSS. and Documents in connexion with the Meteorological Committee's work	"
Working Drawings of Instruments.	
Observatory Correspondence.	
Furniture and Fittings	Met. Com.

Sun Room.

Sun Pictures (Negatives)	Gov. Grant.
Sun Pictures (Prints)	"
Thirty-seven Vols. Schwabe's Observations (MSS.)	Roy. Ast. Soc.
Sundry Papers connected with Solar Research.	
Sundry Volumes of Kew Electrical and Meteorological Observations (MSS.).	
Surplus Lithographed and Engraved copies of Kew Magnetic Curves	Gov. Grant.
Photo-galvanographed Plates of Curves, by Paul Pretsch	"
Spare Magnets for Magnetographs	Mr. Adie.
One Magnetic Tabulator	Brit. Assoc.
Two Magnetic Tabulators	Brit. Assoc., Mr. Gassiot.

Lofts.

Old Observing Clock.	
Parts of old Electrical and Meteorological Apparatus	Brit. Assoc.
Parts of old Royal Society Apparatus	Royal Soc.

Solar Photographic Room.

Anemograph with Blank sheets	Met. Com.
Baths, Dishes, Printing-frames, Bottles, Paper, Che-	

micals, Glass, &c., used in connexion with the Photoheliograph	Gov. Grant.

Dome.

Photoheliograph	Don. Fund.
Robinson's Registering Anemometer (dismounted)	Brit. Assoc.

Roof.

Old Pressure Anemometer (incomplete)	Brit. Assoc.
Old Rain-gauge (incomplete)	,,

Magnetic Observatory.

Declinometer, Dip Circles	Sir E. Sabine.
Sundry Apparatus employed in Magnetic Determinations	,,
Stone Pillars	,,

Workshop (No. 1).

Whitworth Lathe, Planing Machine	Don. Fund.
Holtzapffel Lathe	SirF.Ronalds.
Forge	Don. Fund.
Forge	Brit. Assoc.
Surfaces and Straight Edges	Gov. Grant.
Grindstone	Brit. Assoc.
Vices	,,
Castings and Tools	,,

Workshop (No. 2).

Electro-magnet and Battery	Sir E. Sabine.
Carbonic-acid Gas Generators	Gov. Grant.
Ronalds's Barograph (incomplete)	,,
Gas-holder	Mr. Atkinson.
Glass-blowing Table	Gov. Grant.
Still	,,
Sundry Packing-cases.	

Enclosure.

Self-recording Rain-gauge	Met. Com.
Rain-gauge (ordinary)	Brit. Assoc.
Two Dial Anemometers	Met. Com.
Mowing Machine and sundry other Garden Tools ..	Brit. Assoc.

Verification House.

Stone Pillars for erecting Self-recording Magnetographs	Don. Fund.
Self-recording Barograph, Thermograph, and Anemograph (undergoing examination)	Met. Com.

In the Custody of B. Loewy, Esq., 11 Leverton Street, N.W.

Mr. De La Rue's Micrometer for measuring Astronomical Photographs (in use for measuring the photographs obtained with the heliograph).

Accounts of the Kew Committee of the British Association from September 15, 1870, to August 2, 1871.

RECEIPTS.				£	s.	d.
Received from the General Treasurer				600	0	0
For the verification of Meteorological Instruments:—						
From the Meteorological Office	54	4	0			
From Opticians and others	71	12	9			
				125	16	9
For the verification of Magnetical Instruments				5	10	0
For the construction of Standard Thermometers				11	10	0
From the Meteorological Office:—						
Allowance for 10 months as one of the Observatories of the Meteorological Committee, at £250 per annum	208	6	8			
Extra allowance to Kew as Central Observatory, ten months, at £400 per annum	333	6	8			
For ruling Fiducial lines on curves	68	3	6			
For services of Assistant	12	10	0			
				622	6	10
Balance of grant received from the Royal Society by Professor Balfour Stewart, available for and applied to Magnetic reductions				96	6	1
Profit from sundry commissions				12	1	1
Balance				40	16	3
				£1514	7	0

PAYMENTS.				£	s.	d.
Salaries, &c.:—						
To B. Stewart, Oct. 1st, 1870, to Aug. 1st, 1871	166	13	4			
Ditto, allowance for superintending work connected with the Meteorological Committee, Oct. 1st, 1870, to Aug. 1st, 1271	166	13	4			
Ditto, allowance for petty travelling expenses	10	0	0			
G. Whipple, Oct. 1, 1870, to Aug. 1, 1871	104	3	4			
T. Baker, do. do.	83	6	8			
F. Page, do. do.	66	13	4			
A. Rigby, do. do.	58	6	8			
R. Beckley, Aug. 15, 1870, to Aug. 1, 1871	125	0	0			
J. Foster, Oct. 1, 1870, to Aug. 1, 1871	41	13	4			
A. Hill, Aug. 1, 1870, to Aug. 1, 1871	30	16	0			
				853	6	0
Apparatus, Materials, Tools, &c.				52	7	1
Ironmonger, Carpenter, Mason, &c.				9	15	3
Printing, Stationery, Books, Postage, &c.				35	5	5
Gas and Coals				61	8	9
House Expenses, Chandlery, &c.				66	14	7
Porterage and petty expenses				30	14	8
Meteorological work done at extra hours				44	7	0
Magnetical tabulations done at extra hours and by supernumerary assistants				349	8	3
Rent of Land attached to Observatory				11	0	0
				£1514	7	0
Balance due to Prof. Balfour Stewart				40	16	3

Examined with the vouchers and found correct, the balance due to Prof. Balfour Stewart being forty pounds sixteen shillings and threepence.

14*th July* 1871.

WARREN DE LA RUE.

Outstanding Liabilities, July 18, 1871.

	£	s.	d.
Balance as above	40	16	3
Due on open Accounts	71	18	10
Accruing Salaries	75	0	0
	£197	15	1

Recommendations adopted by the General Committee at the Edinburgh Meeting in August 1871.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

That in future the division of the Section of Biology into the three Departments of Anatomy and Physiology, Anthropology, and Zoology and Botany shall be recognized in the programme of the Association Meetings, and that the President, two Vice-Presidents, and at least three Secretaries shall be nominated, and that the Vice-Presidents and Secretaries who shall take charge of the organization of the several Departments shall be designated respectively before the publication of such programme.

Dr. R. King's motion, "that a Subsection for Ethnology be formed," was rejected.

That the Apparatus, Instruments, &c. mentioned in Appendix III. of the Report of the Kew Committee for the past year be transferred to the charge of the Royal Society.

That the Electrical Apparatus belonging to the British Association, now in possession of the Committee of Electrical Standards, be placed in the Physical Laboratory of Cambridge, in charge of the Professor of Experimental Physics, the apparatus remaining the property of the Association and at the disposal of the Committee.

[For Regulations relating to Organizing Sectional Proceedings, *vide* p. xix.]

Recommendations Involving Grants of Money.

That the sum of £300 be placed at the disposal of the Council for maintaining the establishment of the Kew Observatory.

That Professor Cayley, Professor H. J. S. Smith, Professor Stokes, Sir W. Thomson, and Mr. J. W. L. Glaisher be a Committee for the purpose of reporting on Mathematical Tables, which it may be desirable to compute or reprint; that Mr. J. W. L. Glaisher be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Mr. Edward Crossley, Rev. T. W. Webb, and Rev. R. Harley be a Committee for discussing Observations of Lunar Objects suspected of change; that Mr. Crossley be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Professor Tait, Professor Tyndall, and Dr. Balfour Stewart be a Committee for the purpose of investigating the Thermal Conductivity of Metals; that Professor Tait be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That the Committee on Tides, consisting of Sir W. Thomson, Professor J. C. Adams, Professor J. W. M. Rankine, Mr. J. Oldham, Rear-Admiral Richards, and Mr. W. Parkes, be reappointed; that Colonel Walker, F.R.S., Superintendent of the Trigonometrical Survey of India, be added to the Committee; and that the sum of £200 be placed at their disposal to defray the expenses of calculation during the ensuing year.

That the Committee for reporting on the Rainfall of the British Isles be reappointed, and that this Committee consist of Mr. Charles Brooke, Mr. Glaisher, Professor Phillips, Mr. G. J. Symons, Mr. J. F. Bateman, Mr. R. W. Mylne, Mr. T. Hawksley, Professor J. C. Adams, Mr. C. Tomlinson,

Professor Sylvester, Dr. Pole, Mr. Rogers Field, Professor Ansted, and Mr. Buchan; that Mr. G. J. Symons be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That a Committee on Underground Temperature, consisting of Sir William Thomson, Professor Everett, Sir Charles Lyell, Bart., Professor J. Clerk Maxwell, Professor Phillips, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. Glaisher, Rev. Dr. Graham, Mr. George Maw, Mr. Pengelly, Mr. S. J. Mackie, Professor Edward Hull, and Professor Ansted, be appointed; that Professor J. D. Everett be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Luminous Meteors, consisting of Mr. Glaisher, Mr. R. P. Greg, Mr. Alexander Herschel, and Mr. C. Brooke, be reappointed, and that the sum of £20 be placed at their disposal for the purpose.

That Dr. Huggins, Mr. J. N. Lockyer, Dr. Reynolds, Professor Swan, and Mr. Stoney be a Committee for the purpose of constructing and printing tables of Inverse Wave Lengths, Mr. Stoney to be reporter; and that the sum of £20 be placed at their disposal for the purpose.

That Professor A. W. Williamson, Professor Roscoe, and Professor Frankland be a Committee for the purpose of superintending the Monthly Reports of the progress of Chemistry; and that the sum of £100 be placed at their disposal for the purpose.

Professor A. W. Williamson, Sir W. Thomson, Professor Clerk Maxwell, Professor G. C. Foster, Mr. Abel, Professor Fleeming Jenkin, Mr. Siemens, and Mr. R. Sabine, with power to add to their number, be a Committee for the purpose of testing the New Pyrometer of Mr. Siemens, by whom the chief instrument will be supplied; and that the sum of £30 be placed at their disposal for the purpose.

That Dr. Gladstone, Dr. C. R. A. Wright, and Mr. Chandler Roberts be a Committee for the purpose of investigating the chemical constitution and optical properties of essential oils, such as are used for perfumes; that Mr. Chandler Roberts be the Secretary, and that the sum of £40 be placed at their disposal for the purpose.

That the Committee, consisting of Professor Crum Brown, Professor Tait, and Mr. Dewar, be reappointed for the purpose of continuing experiments on the Thermal Equivalents of the Oxides of Chlorine; and that the sum of £15 be placed at their disposal for the purpose.

That Dr. Duncan, Mr. Henry Woodward, and Mr. Robert Etheridge be a Committee for the purpose of continuing researches in Fossil Crustacea; that Mr. Woodward be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Sir C. Lyell, Bart., Professor Phillips, Sir J. Lubbock, Bart., Mr. J. Evans, Mr. E. Vivian, Mr. W. Pengelly, Mr. G. Busk, Mr. W. B. Dawkins, and Mr. W. A. Sandford be a Committee for the purpose of continuing the Exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Professor Harkness and Mr. James Thomson be a Committee for the purpose of continuing the investigation of Carboniferous Corals with the view of reproducing them for publication; that Mr. Thomson be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. G. Busk and Mr. Boyd Dawkins be a Committee for the purpose of assisting Dr. Leith Adams in the preparation of Plates illustrating an account of the Fossil Elephants of Malta; that Mr. Busk be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Professor Harkness, Mr. William Jolly, and Dr. J. Bryce be a Committee for the purpose of collecting Fossils from localities of difficult access in North-western Scotland, that the specimens be deposited in the Edinburgh Industrial Museum, and that duplicates be deposited in such Museum as the Association may designate; that Mr. William Jolly be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Professor Ramsay, Professor Geikie, Professor J. Young, Professor Nicol, Dr. Bryce, Dr. Arthur Mitchell, Professor Hull, Sir R. Griffith, Bart., Dr. King, Professor Harkness, Mr. Prestwich, Mr. Hughes, and Mr. Pengelly be a Committee for the purpose of ascertaining the existence in different parts of the United Kingdom of any Erratic Blocks or Boulders, indicating on Maps their position and height above the sea, as also of ascertaining the nature of the rocks composing these blocks, their size, shape, and other particulars of interest, and of endeavouring to prevent the destruction of such blocks as in the opinion of the Committee are worthy of being preserved; that Mr. Milne Holme be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Mr. Stainton, Professor Newton, and Sir John Lubbock be a Committee for the purpose of continuing a Record of Zoological Literature; that Mr. Stainton be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Professor Balfour, Dr. Cleghorn, Mr. Robert Hutchinson, Mr. Alexander Buchan, and Mr. John Sadler be a Committee for the purpose of taking Observations on the effect of the Denudation of Timber on the Rainfall in North Britain; that Dr. Cleghorn be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Dr. Sharpey, Dr. Richardson, and Professor Humphry be a Committee for the purpose of continuing investigations on the Physiological Action of Organic Chemical Compounds; that Dr. Richardson be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Professor Michael Foster, Mr. W. H. Flower, and Mr. Benjamin Lowne be a Committee for the purpose of making Terato-embryological inquiries; that Mr. Lowne be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Professor M. Foster, Dr. Arthur Gamgee, and Mr. E. Ray Lankester be a Committee for the purpose of investigating the amount of Heat generated in the Blood in the Process of Arterialization; that Dr. Gamgee be the Secretary, and that the sum of £15 be placed at their disposal for the purpose.

That Professor Christison, Dr. Laycock, and Dr. Fraser be a Committee for the purpose of investigating the Antagonism of Poisonous Substances; that Dr. Fraser be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Sir R. I. Murchison, Bart., the Rev. Dr. Ginsburg, Mr. Hepworth Dixon, Rev. Dr. Tristram, General Chesney, Rev. Professor Rawlinson, and Mr. John A. Tinné be a Committee for the purpose of undertaking a Geographical Exploration of the country of Moab; and that the sum of £100 be placed at their disposal for the purpose, in addition to the sum of £100 granted last year, but not expended because it was found to be insufficient for the purpose.

That the Metric Committee be reappointed, such Committee to consist of Sir John Bowring, The Right Hon. Sir Stafford H. Northcote, Bart., C.B.,

M.P., The Right Hon. Sir C. B. Adderley, M.P., Mr. Samual Brown, Dr. Farr, Mr. Frank P. Fellowes, Professor Frankland, Mr. James Heywood, Professor Leone Levi, Mr. C. W. Siemens, Professor A. W. Williamson, Dr. George Glover, Sir Joseph Whitworth, Bart., Mr. J. R. Napier, Mr. J. V. N. Bazalgette, and Sir W. Fairbairn, Bart.; that Professor Leone Levi be the Secretary, and that the sum of £75 be placed at their disposal for the purpose of being applied solely to scientific purposes, printing, and correspondence.

That Professor W. J. Macquorn Rankine, Mr. Froude, Mr. C. W. Merrifield, Mr. C.W. Siemens, Mr. Bramwell, Mr. L. E. Fletcher, and Mr. James R. Napier be a Committee for the purpose of making experiments on instruments for Measuring the Speed of Ships and Currents by means of the difference of height of two columns of liquids; that Mr. Fletcher be the Secretary, and that the sum of £30 be placed at their disposal for the purpose.

That Mr. R. B. Grantham, Professor Corfield, M.B., Mr. J. Bailey Denton, Dr. J. H. Gilbert, Mr. J. Thornhill Harrison, Mr. William Hope, Lieut.-Col. Leach, Dr. A. Voelcker, and Professor A. W. Williamson be a Committee for the purpose of continuing the investigations on the "Treatment and Utilization of Sewage;" that the balance of the funds raised by the Committee appointed at Exeter, and now in the hands of the General Treasurer, be placed at their disposal for the purpose.

Applications for Reports and Researches not involving Grants of Money.

That the Committee, consisting of Dr. Joule, Sir W. Thomson, Professor Tait, Professor Balfour Stewart, and Professor J. C. Maxwell, be reappointed to effect the determination of the Mechanical Equivalent of Heat.

That Sir W. Thomson, Professor Everett, Professor G. C. Foster, Professor J. C. Maxwell, Mr. G. J. Stoney, Professor Fleeming Jenkin, Professor Rankine, Mr. Siemens, and Mr. Bramwell be a Committee for the purpose of framing a nomenclature of Units of Force and Energy.

That Professor Sylvester, Professor Cayley, Professor Hirst, Rev. Professor Bartholomew Price, Professor H. J. S. Smith, Dr. Spottiswoode, Mr. R. B. Hayward, Dr. Salmon, Rev. R. Townsend, Professor Fuller, Professor Kelland, Mr. J. M. Wilson, and Professor Clifford be reappointed a Committee (with power to add to their number) for the purpose of considering the possibility of improving the methods of instruction in elementary geometry; and that Professor Clifford be the Secretary.

That Mr. W. H. L. Russell be requested to continue his Report on recent progress in the theory of Elliptic and Hyperelliptic Functions.

That Mr. Carruthers, Dr. Hooker, Professor Balfour, and Mr. Dyer be a Committee for the purpose of investigating the Fossil Flora of Britain.

That Rev. Canon Tristram, Professor Newton, Mr. H. E. Dresser, Mr. J. E. Harting, and Rev. H. F. Barnes be reappointed a Committee for the purpose of continuing the investigation on the desirability of establishing "*a close time*" for the preservation of indigenous animals; and that the Rev. Canon Tristram be the Secretary.

That Dr. Rolleston, Dr. Sclater, Dr. Dohrn, Professor Huxley, Professor Wyville Thomson, and Mr. E. Ray Lankester be a Committee for the purpose of promoting the foundation of Zoological Stations; and that Dr. Anton Dohrn be the Secretary.

That the Committee appointed last year "to consider and report on the various plans proposed for legislating on the subject of Steam-boiler Explosions

with a view to their prevention" be requested to continue their labours; such Committee to consist of Sir W. Fairbairn, Bart., Mr. John Penn, Mr. F. J. Bramwell, Mr. Hugh Mason, Mr. Samuel Rigby, Mr. Thomas Schofield, Mr. C. F. Beyer, Mr. T. Webster, Q.C., Mr. Lavington E. Fletcher, and Mr. Edward Easton, with power to add to their number.

That Mr. Bateman, Mr. Le Neve Foster, Mr. Merrifield, Mr. Edward Easton, Mr. F. J. Bramwell, Mr. W. Hope, and Mr. H. Bauerman be a Committee to consider the mode in which new inventions, and claims for reward in respect of adopted inventions, are examined and dealt with by the different Departments of Government, and to report on the best means of removing any real causes of dissatisfaction, as well as of silencing unfounded complaints.

That a Committee be appointed—

1°, to consider and report on the best means of advancing science by Lectures, with authority to act, subject to the approval of the Council, in the course of the present year, if judged desirable.

2°, to consider and report whether any steps can be taken to render scientific organization more complete and effectual.

That the Committee consist of the following Members, with power to add to their number:—Professor Roscoe, Professor W. G. Adams, Professor Andrews, Professor Balfour, Mr. Bramwell, Professor A. Crum Brown, Mr. Dyer, Sir Walter Elliot, Professor Flower, Professor G. C. Foster, Professor Geikie, Rev. R. Harley, Professor Huxley, Professor Fleeming Jenkin, Dr. Joule, Colonel Lane Fox, Dr. Lankester, Mr. J. N. Lockyer, Dr. O'Callaghan, Professor Ramsay, Professor Balfour Stewart, Mr. Stainton, Professor Tait, Mr. J. A. Tinné, Dr. Allen Thomson, Sir William Thomson, Professor Wyville Thomson, Professor Turner, Professor A. W. Williamson, Dr. Young; and that Professor Roscoe be the Secretary.

Resolutions involving Applications to Government.

That the President and Council of the British Association be authorized to cooperate with the President and Council of the Royal Society, in whatever way may seem to them best, for the promotion of a Circumnavigation Expedition, specially fitted out to carry the Physical and Biological Exploration of the Deep Sea into all the Great Oceanic areas.

That the President and General Officers, with power to add to their number, be requested to take such steps as may seem to them desirable in order to promote observations on the forthcoming Total Solar Eclipse.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

That the letter of Lavoisier to Black, referred to in the Address of the President of the Chemical Section, be printed in the Annual Report; and that the letter dated 19th November, 1790, be published in facsimile.

That Mr. Bramwell's paper "On Experiments made with Carr's Disintegrating Flour-mill" be printed *in extenso* in the Transactions of the Association.

Resolutions referred to the Council for consideration and action if it seem desirable.

That it is desirable that the British Association apply to the Treasury for funds to enable the Tidal Committee to continue their calculations.

That it is desirable that the British Association should urge upon the Government of India the importance for navigation and other practical purposes, and for science, of making accurate and continued observations on the Tides at several points on the coast of India.

That the Council of the Association be requested to take such steps as to them may seem most expedient in support of a proposal, made by Dr. Buys Ballot, to establish a telegraphic meteorological station at the Azores.

That the Council be requested to take into consideration the desirability of the publication of a periodic record of advances made in the various branches of science represented by the British Association.

That the Council of this Association be requested to take such steps as may appear to them desirable with reference to the arrangement now in contemplation to establish "leaving Examinations," and to report to the Association on the present position of science-teaching in the public and first-grade schools.

That the Council be requested to take such steps as they deem wisest in order to promote the introduction of scientific instruction into the elementary schools throughout the country.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Edinburgh Meeting in August 1871. *The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.*

	£	s.	d.
Kew Observatory.			
The Council.—Maintaining the Establishment of Kew Observatory	300	0	0
Mathematics and Physics.			
Cayley, Professor.—Mathematical Tables	50	0	0
*Crossley, Mr.—Discussion of Observations of Lunar Objects	20	0	0
*Tait, Professor.—Thermal Conductivity of Metals	25	0	0
*Thomson, Professor Sir W.—Tidal Observations	200	0	0
*Brooke, Mr.—British Rainfall	100	0	0
*Thomson, Sir W.—Underground Temperature	100	0	0
*Glaisher, Mr.—Luminous Meteors	20	0	0
Huggins, Dr.—Tables of Inverse Wave-lengths	20	0	0
Chemistry.			
*Williamson, Prof. A. W.—Reports of the Progress of Chemistry	100	0	0
Williamson, Prof. A. W.—Testing Siemens's new Pyrometer	30	0	0
Gladstone, Dr.—Chemical Constitution and Optical Properties of Essential Oils	40	0	0
*Brown, Dr. Crum.—Thermal Equivalent of the Oxides of Chlorine	15	0	0
Carried forward	£1020	0	0

* Reappointed.

Geology.	£	s.	d.
Brought forward	1020	0	0
*Duncan, Dr.—Fossil Crustacea	25	0	0
*Lyell, Sir C., Bart.—Kent's Cavern Exploration	100	0	0
*Harkness, Professor.—Investigation of Fossil Corals	25	0	0
*Busk, Mr.—Fossil Elephants of Malta (renewed)	25	0	0
Harkness, Professor.—Collection of Fossils in the North-west of Scotland	10	0	0
Ramsay, Professor.—Mapping Positions of Erratic Blocks and Boulders	10	0	0
Biology.			
*Stainton, Mr.—Record of the Progress of Zoology	100	0	0
*Balfour, Professor.—Effect of the Denudation of Timber on the Rainfall in North Britain (renewed)	20	0	0
*Sharpey, Dr.—Physiological Action of Organic Compounds	25	0	0
Foster, Professor M.—Terato-embryological Inquiries	20	0	0
Foster, Professor M.—Heat Generated in the Arterialization of the Blood (part renewed)	15	0	0
Christison, Professor.—Antagonism of Poisonous Substances	20	0	0
Geography.			
*Murchison, Sir R. Bart.—Exploration of the Country of Moab	100	0	0
Economic Science and Statistics.			
*Bowring, Sir J.—Metric Committee	75	0	0
Mechanics.			
Rankine, Professor.—Experiments on Instruments for Measuring the Speed of Ships and Currents	30	0	0
Total	£1620	0	0

* Reappointed.

Place of Meeting in 1873.

It was resolved that the Annual Meeting of the Association in 1873 be held at Bradford.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6

	£	s.	d.
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Cooperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Cooperation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars ... 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	10	0	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£345	18	0

	£	s.	d.
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4
1858.			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859.			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1
1860.			
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0

	£	s.	d.
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860 ...... £50 0 0; 1861 ...... £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0

	£	s.	d.
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	0
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c. Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyle and Methyle series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl series	25	0	0
Mercury and Bile	25	0	0
Organic remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0

	£	s.	d.
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Corals Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

General Meetings.

On Wednesday Evening, August 2, at 8 P.M., in the Music Hall, Professor T. H. Huxley, LL.D., F.R.S., F.L.S., President, resigned the office of President to Professor Sir William Thomson, LL.D., F.R.S., who took the Chair, and delivered an Address, for which see page lxxxiv.

On Thursday Evening, August 3, at 8.30 P.M., in the Music Hall, F. A. Abel, Esq. F.R.S., Director of the Chemical Department, Royal Arsenal, Woolwich, delivered a Discourse on "Some Recent Investigations and Applications of Explosive Agents."

On Friday Evening, August 4, at 8 P.M., a Soirée took place in the University Library.

On Monday Evening, August 7, at 8.30 P.M., in the Music Hall, E. B. Tylor, Esq., delivered a Discourse on "The Relation of Primitive to Modern Civilization."

On Tuesday Evening, August 8, at 8 P.M., a Soirée took place in the Museum of Science and Art.

On Wednesday, August 9, at 2.30 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Brighton*.

* The Meeting is appointed to take place on Wednesday, August 14, 1872.

ADDRESS

OF

Sir WILLIAM THOMSON, Knt., LL.D., F.R.S.,

PRESIDENT.

For the third time of its forty years' history the British Association is assembled in the metropolis of Scotland. The origin of the Association is connected with Edinburgh in undying memory through the honoured names of Robison, Brewster, Forbes, and Johnston.

In this place, from this Chair, twenty-one years ago, Sir David Brewster said:—"On the return of the British Association to the metropolis of Scot-"land I am naturally reminded of the small band of pilgrims who carried "the seeds of this Institution into the more genial soil of our sister land." . . . . . "Sir John Robison, Professor Johnston, and Professor J. D. "Forbes were the earliest friends and promoters of the British Association. "They went to York to assist in its establishment, and they found there the "very men who were qualified to foster and organize it. The Rev. Mr. "Vernon Harcourt, whose name cannot be mentioned here without grati-"tude, had provided laws for its government, and, along with Mr. Phillips, "the oldest and most valuable of our office-bearers, had made all those "arrangements by which its success was ensured. Headed by Sir Roderick "Murchison, one of the very earliest and most active advocates of the "Association, there assembled at York about 200 of the friends of science."

The statement I have read contains no allusion to the real origin of the British Association. This blank in my predecessor's historical sketch I am able to fill in from words written by himself twenty years earlier. Through the kindness of Professor Phillips I am enabled to read to you part of a letter to him at York, written by David Brewster from Allerly by Melrose, on the 23rd of February, 1831:—

"Dear Sir,—I have taken the liberty of writing you on a subject of con-"siderable importance. It is proposed to establish a British Association of "men of science similar to that which has existed for eight years in Ger-"many, and which is now patronized by the most powerful Sovereigns of that "part of Europe. The arrangements for the first meeting are in progress; and "it is contemplated that it shall be held in York, as the most central city for "the three kingdoms. My object in writing you at present is to beg that you "would ascertain if York will furnish the accommodation necessary for so

" large a meeting (which may perhaps consist of above 100 individuals), if " the Philosophical Society would enter zealously into the plan, and if the " Mayor and influential persons in the town and in the vicinity would be " likely to promote its objects. The principal object of the Society would " be to make the cultivators of science acquainted with each other, to stimu- " late one another to new exertions, and to bring the objects of science more " before the public eye, and to take measures for advancing its interests " and accelerating its progress."

Of the little band of four pilgrims from Scotland to York, not one now survives. Of the seven first Associates one more has gone over to the majority since the Association last met. Vernon Harcourt is no longer with us; but his influence remains, a beneficent and, surely therefore, never dying influence. He was a Geologist and Chemist, a large-hearted lover of science, and an unwearied worker for its advancement. Brewster was the founder of the British Association; Vernon Harcourt was its law-giver. His code remains to this day the law of the Association.

On the eleventh of May last Sir John Herschel died, in the eightieth year of his age. The name of Herschel is a household word throughout Great Britain and Ireland—yes, and through the whole civilized world. We of this generation have, from our lessons of childhood upwards, learned to see in Herschel, father and son, a *præsidium et dulce decus* of the precious treasure of British scientific fame. When geography, astronomy, and the use of the globes were still taught, even to poor children, as a pleasant and profitable sequel to "reading, writing, and arithmetic," which of us did not revere the great telescope of Sir William Herschel (one of the Hundred Wonders of the World), and learn with delight, directly or indirectly from the charming pages of Sir John Herschel's book, about the sun and his spots, and the fiery tornadoes sweeping over his surface, and about the planets, and Jupiter's belts, and Saturn's rings, and the fixed stars with their proper motions, and the double stars, and coloured stars, and the nebulæ discovered by the great telescope? Of Sir John Herschel it may indeed be said, *nil tetigit quod non ornavit.*

A monument to Faraday and a monument to Herschel, Britain must have. The nation will not be satisfied with any thing, however splendid, done by private subscription. A national monument, the more humble in point of expense the better, is required to satisfy that honourable pride with which a high-spirited nation cherishes the memory of its great men. But for the glory of Faraday or the glory of Herschel, is a monument wanted? No!

> What needs my Shakespere for his honoured bones
> The labour of an age in piled stones?
> Or that his hallowed reliques should be hid
> Under a star-ypointing pyramid?
> Dear son of memory, great heir of fame,
> What need'st thou such weak witness of thy name!
> Thou, in our wonder and astonishment,
> Hast built thyself a live-long monument.
>
> * * * *
>
> And, so sepúlchred, in such pomp dost lie,
> That kings for such a tomb would wish to die.

With regard to Sir John Herschel's scientific work, on the present occasion I can but refer briefly to a few points which seem to me salient in his physical and mathematical writings. First, I remark that he has put forward, most instructively and profitably to his readers, the general theory of periodicity in dynamics, and has urged the practical utilizing of it, espe-

cially in meteorology, by the harmonic analysis. It is purely by an application of this principle and practical method, that the British Association's Committee on Tides has for the last four years been, and still is, working towards the solution of the grand problem proposed forty-eight years ago by Thomas Young in the following words :—

"There is, indeed, little doubt that if we were provided with a sufficiently "correct series of minutely accurate observations on the Tides, made not merely "with a view to the times of low and high water only, but rather to the heights "at the intermediate times, we might form, by degrees, with the assistance "of the theory contained in this article* only, almost as perfect a set of tables "for the motions of the ocean as we have already obtained for those of the "celestial bodies, which are the more immediate objects of the attention of "the practical astronomer."

Sir John Herschel's discovery of a right or left-handed asymmetry in the outward form of crystals, such as quartz, which in their inner molecular structure possess the heliçoidal rotational property in reference to the plane of polarization of light, is one of the notable points of meeting between Natural History and Natural Philosophy. His observations on "epipolic dispersion" gave Stokes the clue by which he was led to his great discovery of the change of periodic time experienced by light in falling on certain substances and being dispersively reflected from them. In respect to pure mathematics Sir John Herschel did more, I believe, than any other man to introduce into Britain the powerful methods and the valuable notation of modern analysis. A remarkable mode of symbolism had freshly appeared, I believe, in the works of Laplace, and possibly of other French mathematicians ; it certainly appeared in Fourier, but whether before or after Herschel's work I cannot say. With the French writers, however, this was rather a short method of writing formulæ than the analytical engine which it became in the hands of Herschel and British followers, especially Sylvester and Gregory (competitors with Green in the Cambridge Mathematical Tripos struggle of 1837) and Boole and Cayley. This method was greatly advanced by Gregory, who first gave to its working-power a secure and philosophical foundation, and so prepared the way for the marvellous extension it has received from Boole, Sylvester, and Cayley, according to which symbols of operation become the subjects not merely of algebraic combination, but of differentiations and integrations, as if they were symbols expressing values of varying quantities. An even more marvellous development of this same idea of the separation of symbols (according to which Gregory separated the algebraic signs + and − from other symbols or quantities to be characterized by them, and dealt with them according to the laws of algebraic combination) received from Hamilton a most astonishing generalization, by the invention actually of new laws of combination, and led him to his famous "Quaternions," of which he gave his earliest exposition to the Mathematical and Physical Section of this Association, at its meeting in Cambridge in the year 1845. Tait has taken up the subject of quaternions ably and zealously, and has carried it into physical science with a faith, shared by some of the most thoughtful mathematical naturalists of the day, that it is destined to become an engine of perhaps hitherto unimagined power for investigating and expressing results in Natural Philosophy. Of Herschel's gigantic work in astronomical observation I need say nothing. Doubtless a careful account of it will be given in the 'Proceedings of the Royal Society of London' for the next anniversary meeting.

* Young's; written in 1823 for the Supplement to the 'Encyclopædia Britannica.'

In the past year another representative man of British science is gone. Mathematics has had no steadier supporter for half a century than De Morgan. His great book on the differential calculus was, for the mathematical student of thirty years ago, a highly prized repository of all the best things that could be brought together under that title. I do not believe it is less valuable now; and if it is less valued, may this not be because it is too good for examination purposes, and because the modern student, labouring to win marks in the struggle for existence, must not suffer himself to be beguiled from the stern path of duty by any attractive beauties in the subject of his study?

One of the most valuable services to science which the British Association has performed has been the establishment, and the twenty-nine years' maintenance, of its Observatory. The Royal Meteorological Observatory of Kew was built originally for a Sovereign of England who was a zealous amateur of astronomy. George the Third used continually to repair to it when any celestial phenomenon of peculiar interest was to be seen; and a manuscript book still exists filled with observations written into it by his own hand. After the building had been many years unused, it was granted, in the year 1842, by the Commissioners of Her Majesty's Woods and Forests, on application of Sir Edward Sabine, for the purpose of continuing observations (from which he had already deduced important results) regarding the vibration of a pendulum in various gases, and for the purpose of promoting pendulum observations in all parts of the world. The Government granted only the building—no funds for carrying on the work to be done in it. The Royal Society was unable to undertake the maintenance of such an observatory; but, happily for science, the zeal of individual Fellows of the Royal Society and Members of the British Association gave the initial impulse, supplied the necessary initial funds, and recommended their new institution successfully to the fostering care of the British Association. The work of the Kew Observatory has, from the commencement, been conducted under the direction of a Committee of the British Association; and annual grants from the funds of the Association have been made towards defraying its expenses up to the present time. To the initial object of pendulum research was added continuous observation of the phenomena of meteorology and terrestrial magnetism, and the construction and verification of thermometers, barometers, and magnetometers designed for accurate measurement. The magnificent services which it has rendered to science are so well known that any statement of them which I could attempt on the present occasion would be superfluous. Their value is due in a great measure to the indefatigable zeal and the great ability of two Scotchmen, both from Edinburgh, who successively held the office of Superintendent of the Observatory of the British Association—Mr. Welsh for nine years, until his death in 1859, and Dr. Balfour Stewart from then until the present time. Fruits of their labours are to be found all through our volumes of Reports for these twenty-one years.

The institution now enters on a new stage of its existence. The noble liberality of a private benefactor, one who has laboured for its welfare with self-sacrificing devotion unintermittingly from within a few years of its creation, has given it a permanent independence, under the general management of a Committee of the Royal Society. Mr. Gassiot's gift of £10,000 secures the continuance at Kew of the regular operation of the self-recording instruments for observing the phenomena of terrestrial magnetism and meteorology, without the necessity for further support from the British Association.

The success of the Kew Magnetic and Meteorological Observatory affords an example of the great gain to be earned for science by the foundation of physical observatories and laboratories for experimental research, to be conducted by qualified persons, whose duties should be, not teaching, but experimenting. Whether we look to the honour of England, as a nation which ought always to be the foremost in promoting physical science, or to those vast economical advantages which must accrue from such establishments, we cannot but feel that experimental research ought to be made with us an object of national concern, and not left, as hitherto, exclusively to the private enterprise of self-sacrificing amateurs, and the necessarily inconsecutive action of our present Governmental Departments and of casual Committees. The Council of the Royal Society of Edinburgh has moved for this object in a memorial presented by them to the Royal Commission on Scientific Education and the Advancement of Science. The Continent of Europe is referred to for an example to be followed with advantage in this country, in the following words:—

"On the Continent there exist certain institutions, fitted with instruments, "apparatus, chemicals, and other appliances, which are meant to be, and "which are made, available to men of science, to enable them, at a moderate "cost, to pursue original researches."

This statement is fully corroborated by information, on good authority, which I have received from Germany, to the effect that in Prussia "every "university, every polytechnical academy, every industrial school (Realschule "and Gewerbeschule), most of the grammar-schools, in a word, nearly all the "schools superior in rank to the elementary schools of the common people, are "supplied with chemical laboratories and a collection of philosophical in- "struments and apparatus, access to which is most liberally granted by the "directors of those schools, or the teachers of the respective disciplines, to "any person qualified, for *scientific experiments*. In consequence, though "there exist no particular institutions like those mentioned in the me- "morial, there will scarcely be found a town exceeding in number 5000 "inhabitants but offers the possibility of *scientific explorations* at no other "cost than reimbursement of the expense for the materials wasted in the "experiments."

Further, with reference to a remark in the Memorial to the effect that, in respect to the promotion of science, the British Government confines its action almost exclusively to scientific instruction, and fatally neglects the advancement of science, my informant tells me that, in Germany, "professors, "preceptors, and teachers of secondary schools are engaged on account of "their skilfulness in *teaching*; but professors of universities are never engaged "unless they have already proved, *by their own investigations*, that they are "to be relied upon for the *advancement of science*. Therefore every shilling "spent for instruction in universities is at the same time profitable to the ad- "vancement of science."

The physical laboratories which have grown up in the Universities of Glasgow and Edinburgh, and in Owens College, Manchester, show the want felt of Colleges of Research; but they go but infinitesimally towards supplying it, being absolutely destitute of means, material or personal, for advancing science except at the expense of volunteers, or securing that volunteers shall be found to continue even such little work as at present is carried on.

The whole of Andrews' splendid work in Queen's College, Belfast, has been done under great difficulties and disadvantages, and at great personal sacrifices; and up to the present time there is not a student's physical

laboratory in any one of the Queen's Colleges in Ireland—a want which surely ought not to remain unsupplied. Each of these institutions (the four Scotch Universities, the three Queen's Colleges, and Owens College, Manchester) requires two professors of Natural Philosophy—one who shall be responsible for the teaching, the other for the advancement of science by experiment. The University of Oxford has already established a physical laboratory. The munificence of its Chancellor is about to supply the University of Cambridge with a splendid laboratory, to be constructed under the eye of Professor Clerk Maxwell. On this subject I shall say no more at present, but simply read a sentence which was spoken by Lord Milton in the first Presidential Address to the British Association, when it met at York in the year 1831 :—" In addition to other more direct benefits, these meetings " [of the British Association], I hope, will be the means of impressing on the " Government the conviction, that the love of scientific pursuits, and the " means of pursuing them, are not confined to the metropolis; and I hope " that when the Government is fully impressed with the knowledge of the " great desire entertained to promote science in every part of the empire, they " will see the necessity of affording it due encouragement, and of giving every " proper stimulus to its advancement."

Besides abstracts of papers read, and discussions held, before the Sections, the annual Reports of the British Association contain a large mass of valuable matter of another class. It was an early practice of the Association, a practice that might well be further developed, to call occasionally for a special report on some particular branch of science from a man eminently qualified for the task. The reports received in compliance with these invitations have all done good service in their time, and they remain permanently useful as landmarks in the history of science. Some of them have led to vast practical results; others of a more abstract character are valuable to this day as powerful and instructive condensations and expositions of the branches of science to which they relate. I cannot better illustrate the two kinds of efficiency realized in this department of the Association's work than by referring to Cayley's Report on Abstract Dynamics * and Sabine's Report on Terrestrial Magnetism † (1838).

To the great value of the former, personal experience of benefit received enables me, and gratitude impels me, to testify. In a few pages full of precious matter, the generalized dynamical equations of Lagrange, the great principle evolved from Maupertuis' " least action " by Hamilton, and the later developments and applications of the Hamiltonian principle by other authors are described by Cayley so suggestively that the reading of thousands of quarto pages of papers scattered through the Transactions of the various learned Societies of Europe is rendered superfluous for any one who desires only the essence of these investigations, with no more of detail than is necessary for a thorough and practical understanding of the subject.

Sabine's Report of 1838 concludes with the following sentence :—" Viewed " in itself and its various relations, the magnetism of the earth cannot " be counted less than one of the most important branches of the physical " history of the planet we inhabit; and we may feel quite assured that the " completion of our knowledge of its distribution on the surface of the earth

* Report on the Recent Progress of Theoretical Dynamics, by A. Cayley (Report of the British Association 1857, p. 1).

† Report on the Variations of the Magnetic Intensity observed at different points of the Earth's Surface, by Major Sabine, F.R.S. (forming part of the 7th Report of the British Association).

"would be regarded by our contemporaries and by posterity as a fitting "enterprise of a maritime people, and a worthy achievement of a nation "which has ever sought to rank foremost in every arduous and honourable "undertaking." An immediate result of this Report was that the enterprise which it proposed was recommended to the Government by a joint Committee of the British Association and the Royal Society with such success, that Capt. James Ross was sent in command of the 'Erebus' and 'Terror' to make a magnetic survey of the Antarctic regions, and to plant on his way three Magnetical and Meteorological Observatories, at St. Helena, the Cape, and Van Diemen's Land. A vast mass of precious observations, made chiefly on board ship, were brought home from this expedition. To deduce the desired results from them, it was necessary to eliminate the disturbance produced by the ship's magnetism; and Sabine asked his friend Archibald Smith to work out from Poisson's mathematical theory, then the only available guide, the formulæ required for the purpose. This voluntary task Smith executed skilfully and successfully. It was the beginning of a series of labours carried on with most remarkable practical tact, with thorough analytical skill, and with a rare extreme of disinterestedness, in the intervals of an arduous profession, for the purpose of perfecting and simplifying the correction of the mariner's compass—a problem which had become one of vital importance for navigation, on account of the introduction of iron ships. Edition after edition of the 'Admiralty Compass Manual' has been produced by the able superintendent of the Compass Department, Captain Evans, containing chapters of mathematical investigation and formulæ by Smith, on which depend wholly the practical analysis of compass-observations, and rules for the safe use of the compass in navigation. I firmly believe that it is to the thoroughly scientific method thus adopted by the Admiralty, that no iron ship of Her Majesty's Navy has ever been lost through errors of the compass. The 'British Admiralty Compass Manual' is adopted as a guide by all the navies of the world. It has been translated into Russian, German, and Portuguese; and it is at present being translated into French. The British Association may be gratified to know that the possibility of navigating ironclad war-ships with safety depends on application of scientific principles given to the world by three mathematicians, Poisson, Airy, and Archibald Smith.

Returning to the science of terrestrial magnetism, we find in the Reports of early years of the British Association ample evidence of its diligent cultivation. Many of the chief scientific men of the day from England, Scotland, and Ireland found a strong attraction to the Association in the facilities which it afforded to them for cooperating in their work on this subject. Lloyd, Phillips, Fox, Ross, and Sabine made magnetic observations all over Great Britain; and their results, collected by Sabine, gave for the first time an accurate and complete survey of terrestrial magnetism over the area of this island. I am informed by Professor Phillips that, in the beginning of the Association, Herschel, though a "sincere well-wisher," felt doubts as to the general utility and probable success of the plan and purpose proposed; but his zeal for terrestrial magnetism brought him from being merely a sincere well-wisher to join actively and cordially in the work of the Association. "In 1838 he began to give effec- "tual aid in the great question of magnetical Observatories, and was indeed "foremost among the supporters of that which is really Sabine's great work. "At intervals, until about 1858, Herschel continued to give effectual aid." Sabine has carried on his great work without intermission to the present day; thirty years ago he gave to Gauss a large part of the data required

for working out the spherical harmonic analysis of terrestrial magnetism over the whole earth. A recalculation of the harmonic analysis for the altered state of terrestrial magnetism of the present time has been undertaken by Adams. He writes to me that he has "already begun some of the introduc-"tory work, so as to be ready when Sir Edward Sabine's Tables of the values "of the Magnetic Elements deduced from observation are completed, at once "to make use of them," and that he intends to take into account terms of at least one order beyond those included by Gauss. The form in which the requisite data are to be presented to him is a magnetic Chart of the whole surface of the globe. Materials from scientific travellers of all nations, from our home magnetic observatories, from the magnetic observatories of St. Helena, the Cape, Van Diemen's Land, and Toronto, and from the scientific observatories of other countries have been brought together by Sabine. Silently, day after day, night after night, for a quarter of a century he has toiled with one constant assistant always by his side to reduce these observations and prepare for the great work. At this moment, while we are here assembled, I believe that, in their quiet summer retirement in Wales, Sir Edward and Lady Sabine are at work on the magnetic Chart of the world. If two years of life and health are granted to them, science will be provided with a key which must powerfully conduce to the ultimate opening up of one of the most refractory enigmas of cosmical physics, the cause of terrestrial magnetism.

To give any sketch, however slight, of scientific investigation performed during the past year would, even if I were competent for the task, far exceed the limits within which I am confined on the present occasion. A detailed account of work done and knowledge gained in science Britain ought to have every year. The Journal of the Chemical Society and the Zoological Record do excellent service by giving abstracts of all papers published in their departments. The admirable example afforded by the German "Fortschritte" and "Jahresbericht" is before us; but hitherto, so far as I know, no attempt has been made to follow it in Britain. It is true that several of the annual volumes of the Jahresbericht were translated; but a translation, published necessarily at a considerable interval of time after the original, cannot supply the want. An independent British publication is for many obvious reasons desirable. The two publications, in German and English, would, both by their differences and by their agreements, illustrate the progress of science more correctly and usefully than any single work could do, even if appearing simultaneously in the two languages. It seems to me that to promote the establishment of a British Year Book of Science is an object to which the powerful action of the British Association would be thoroughly appropriate.

In referring to recent advances in several branches of science, I simply choose some of those which have struck me as most notable.

Accurate and minute measurement seems to the non-scientific imagination a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labour in the minute sifting of numerical results. The popular idea of Newton's grandest discovery is that the theory of gravitation flashed into his mind, and so the discovery was made. It was by a long train of mathematical calculation, founded on results accumulated through prodigious toil of practical astronomers, that Newton first demonstrated the forces urging the planets towards the Sun, determined the magnitudes of those forces, and discovered that a force fol-

lowing the same law of variation with distance urges the Moon towards the Earth. *Then* first, we may suppose, came to him the idea of the universality of gravitation; but when he attempted to compare the magnitude of the force on the Moon with the magnitude of the force of gravitation of a heavy body of equal mass at the earth's surface, he did not find the agreement which the law he was discovering required. Not for years after would he publish his discovery as made. It is recounted that, being present at a meeting of the Royal Society, he heard a paper read, describing geodesic measurement by Picard which led to a serious correction of the previously accepted estimate of the Earth's radius. This was what Newton required. He went home with the result, and commenced his calculations, but felt so much agitated that he handed over the arithmetical work to a friend: then (and not when, sitting in a garden, he saw an apple fall) did he ascertain that gravitation keeps the Moon in her orbit.

Faraday's discovery of specific inductive capacity, which inaugurated the new philosophy, tending to discard action at a distance, was the result of minute and accurate measurement of electric forces.

Joule's discovery of thermo-dynamic law through the regions of electro-chemistry, electro-magnetism, and elasticity of gases was based on a delicacy of thermometry which seemed simply impossible to some of the most distinguished chemists of the day.

Andrews' discovery of the continuity between the gaseous and liquid states was worked out by many years of laborious and minute measurement of phenomena scarcely sensible to the naked eye.

Great service has been done to science by the British Association in promoting accurate measurement in various subjects. The origin of exact science in terrestrial magnetism is traceable to Gauss' invention of methods of finding the magnetic intensity in absolute measure. I have spoken of the great work done by the British Association in carrying out the application of this invention in all parts of the world. Gauss' colleague in the German Magnetic Union, Weber, extended the practice of absolute measurement to electric currents, the resistance of an electric conductor, and the electromotive force of a galvanic element. He showed the relation between electrostatic and electromagnetic units for absolute measurement, and made the beautiful discovery that resistance, in absolute electromagnetic measure, and the reciprocal of resistance, or, as we call it, "conducting power," in electrostatic measure, are each of them a velocity. He made an elaborate and difficult series of experiments to measure the velocity which is equal to the conducting power, in electrostatic measure, and at the same time to the resistance in electromagnetic measure, in one and the same conductor. Maxwell, in making the first advance along a road of which Faraday was the pioneer, discovered that this velocity is physically related to the velocity of light, and that, on a certain hypothesis regarding the elastic medium concerned, it may be exactly equal to the velocity of light. Weber's measurement verifies approximately this equality, and stands in science *monumentum œre perennius*, celebrated as having suggested this most grand theory, and as having afforded the first quantitative test of the recondite properties of matter on which the relations between electricity and light depend. A remeasurement of Weber's critical velocity on a new plan by Maxwell himself, and the important correction of the velocity of light by Foucault's laboratory experiments, verified by astronomical observation, seem to show a still closer agreement. The most accurate possible determination of Weber's critical velocity is just now a primary object of the Association's

Committee on Electric Measurement; and it is at present premature to speculate as to the closeness of the agreement between that velocity and the velocity of light. This leads me to remark how much science, even in its most lofty speculations, gains in return for benefits conferred by its application to promote the social and material welfare of man. Those who perilled and lost their money in the original Atlantic Telegraph were impelled and supported by a sense of the grandeur of their enterprise, and of the world-wide benefits which must flow from its success; they were at the same time not unmoved by the beauty of the scientific problem directly presented to them; but they little thought that it was to be immediately, through their work, that the scientific world was to be instructed in a long-neglected and discredited fundamental electric discovery of Faraday's, or that, again, when the assistance of the British Association was invoked to supply their electricians with methods for absolute measurement (which they found necessary to secure the best economical return for their expenditure, and to obviate and detect those faults in their electric material which had led to disaster), they were laying the foundation for accurate electric measurement in every scientific laboratory in the world, and initiating a train of investigation which now sends up branches into the loftiest regions and subtlest ether of natural philosophy. Long may the British Association continue a bond of union, and a medium for the interchange of good offices between science and the world!

The greatest achievement yet made in molecular theory of the properties of matter is the Kinetic theory of Gases, shadowed forth by Lucretius, definitely stated by Daniel Bernoulli, largely developed by Herapath, made a reality by Joule, and worked out to its present advanced state by Clausius and Maxwell. Joule, from his dynamical equivalent of heat, and his experiments upon the heat produced by the condensation of gas, was able to estimate the average velocity of the ultimate molecules or atoms composing it. His estimate for hydrogen was 6225 feet per second at temperature 60° Fahr., and 6055 feet per second at the freezing-point. Clausius took fully into account the impacts of molecules on one another, and the kinetic energy of *relative* motions of the matter constituting an individual atom. He investigated the relation between their diameters, the number in a given space, and the mean length of path from impact to impact, and so gave the foundation for estimates of the absolute dimensions of atoms, to which I shall refer later. He explained the slowness of gaseous diffusion by the mutual impacts of the atoms, and laid a secure foundation for a complete theory of the diffusion of fluids, previously a most refractory enigma. The deeply penetrating genius of Maxwell brought in viscosity and thermal conductivity, and thus completed the dynamical explanation of all the known properties of gases, except their electric resistance and brittleness to electric force.

No such comprehensive molecular theory had ever been even imagined before the nineteenth century. Definite and complete in its area as it is, it is but a well-drawn part of a great chart, in which all physical science will be represented with every property of matter shown in dynamical relation to the whole. The prospect we now have of an early completion of this chart is based on the assumption of atoms. But there can be no permanent satisfaction to the mind in explaining heat, light, elasticity, diffusion, electricity and magnetism, in gases, liquids, and solids, and describing precisely the relations of these different states of matter to one another by statistics of great numbers of atoms, when the properties of the atom itself are simply assumed. When the theory, of which we have the first

instalment in Clausius and Maxwell's work, is complete, we are but brought face to face with a superlatively grand question, what is the inner mechanism of the atom?

In the answer to this question we must find the explanation not only of the atomic elasticity, by which the atom is a chronometric vibrator according to Stokes's discovery, but of chemical affinity and of the differences of quality of different chemical elements, at present a mere mystery in science. Helmholtz's exquisite theory of vortex-motion in an incompressible frictionless liquid has been suggested as a finger-post, pointing a way which may possibly lead to a full understanding of the properties of atoms, carrying out the grand conception of Lucretius, who "admits no subtle "ethers, no variety of elements with fiery, or watery, or light, or heavy "principles; nor supposes light to be one thing, fire another, electricity a "fluid, magnetism a vital principle, but treats all phenomena as mere pro-"perties or accidents of simple matter." This statement I take from an admirable paper on the atomic theory of Lucretius, which appeared in the 'North British Review' for March 1868, containing a most interesting and instructive summary of ancient and modern doctrine regarding atoms. Allow me to read from that article one other short passage finely describing the present aspect of atomic theory:—"The existence of the chemical "atom, already quite a complex little world, seems very probable; and "the description of the Lucretian atom is wonderfully applicable to it. We "are not wholly without hope that the real weight of each such atom may "some day be known—not merely the relative weight of the several atoms, "but the number in a given volume of any material; that the form and "motion of the parts of each atom and the distances by which they are "separated may be calculated; that the motions by which they produce heat, "electricity, and light may be illustrated by exact geometrical diagrams; and "that the fundamental properties of the intermediate and possibly constituent "medium may be arrived at. Then the motion of planets and music of the "spheres will be neglected for a while in admiration of the maze in which "the tiny atoms run."

Even before this was written some of the anticipated results had been partially attained. Loschmidt in Vienna had shown, and not much latter Stoney independently in England showed, how to deduce from Clausius and Maxwell's kinetic theory of gases a superior limit to the number of atoms in a given measurable space. I was unfortunately quite unaware of what Loschmidt and Stoney had done when I made a similar estimate on the same foundation, and communicated it to 'Nature' in an article on "The Size of Atoms." But questions of personal priority, however interesting they may be to the persons concerned, sink into insignificance in the prospect of any gain of deeper insight into the secrets of nature. The triple coincidence of independent reasoning in this case is valuable as confirmation of a conclusion violently contravening ideas and opinions which had been almost universally held regarding the dimensions of the molecular structure of matter. Chemists and other naturalists had been in the habit of evading questions as to the hardness or indivisibility of atoms by virtually assuming them to be infinitely small and infinitely numerous. We must now no longer look upon the atom, with Boscovich, as a mystic point endowed with inertia and the attribute of attracting or repelling other such centres with forces depending upon the intervening distances (a supposition only tolerated with the tacit assumption that the inertia and attraction of each atom is infinitely small and the number of atoms infinitely great), nor can we agree with those who have

attributed to the atom occupation of space with infinite hardness and strength (incredible in any finite body); but we must realize it as a piece of matter of measurable dimensions, with shape, motion, and laws of action, intelligible subjects of scientific investigation.

The prismatic analysis of light discovered by Newton was estimated by himself as being "the oddest, if not the most considerable, detection which "hath hitherto been made in the operations of nature."

Had he not been deflected from the subject, he could not have failed to obtain a pure spectrum; but this, with the inevitably consequent discovery of the dark lines, was reserved for the nineteenth century. Our fundamental knowledge of the dark lines is due solely to Fraunhofer. Wollaston saw them, but did not discover them. Brewster laboured long and well to perfect the prismatic analysis of sunlight; and his observations on the dark bands produced by the absorption of interposed gases and vapours laid important foundations for the grand superstructure which he scarcely lived to see. Piazzi Smyth, by spectroscopic observation performed on the Peak of Teneriffe, added greatly to our knowledge of the dark lines produced in the solar spectrum by the absorption of our own atmosphere. The prism became an instrument for chemical qualitative analysis in the hands of Fox Talbot and Herschel, who first showed how, through it, the old "blowpipe test" or generally the estimation of substances from the colours which they give to flames, can be prosecuted with an accuracy and a discriminating power not to be attained when the colour is judged by the unaided eye. But the application of this test to solar and stellar chemistry had never, I believe, been suggested, either directly or indirectly, by any other naturalist, when Stokes taught it to me in Cambridge at some time prior to the summer of 1852. The observational and experimental foundations on which he built were:—

(1) The discovery by Fraunhofer of a coincidence between his double dark line D of the solar spectrum and a double bright line which he observed in the spectra of ordinary artificial flames.

(2) A very rigorous experimental test of this coincidence by Prof. W. H. Miller, which showed it to be accurate to an astonishing degree of minuteness.

(3) The fact that the yellow light given out when salt is thrown on burning spirit consists almost solely of the two nearly identical qualities which constitute that double bright line.

(4) Observations made by Stokes himself, which showed the bright line D to be absent in a candle-flame when the wick was snuffed clean, so as not to project into the luminous envelope, and from an alcohol flame when the spirit was burned in a watch-glass. And

(5) Foucault's admirable discovery (L'Institut, Feb. 7, 1849) that the voltaic arc between charcoal points is "a medium which emits the rays D "on its own account, and at the same time absorbs them when they come "from another quarter."

The conclusions, theoretical and practical, which Stokes taught me, and which I gave regularly afterwards in my public lectures in the University of Glasgow, were:—

(1) That the double line D, whether bright or dark, is due to vapour of sodium.

(2) That the ultimate atom of sodium is susceptible of regular elastic vibrations, like those of a tuning-fork or of stringed musical instruments; that like an instrument with two strings tuned to approximate unison, or an approximately circular elastic disk, it has two fundamental notes or vibrations

of approximately equal pitch; and that the periods of these vibrations are precisely the periods of the two slightly different yellow lights constituting the double bright line D.

(3) That when vapour of sodium is at a high enough temperature to become itself a source of light, each atom executes these two fundamental vibrations simultaneously; and that therefore the light proceeding from it is of the two qualities constituting the double bright line D.

(4) That when vapour of sodium is present in space across which light from another source is propagated, its atoms, according to a well-known general principle of dynamics, are set to vibrate in either or both of those fundamental modes, if some of the incident light is of one or other of their periods, or some of one and some of the other; so that the energy of the waves of those particular qualities of light is converted into thermal vibrations of the medium and dispersed in all directions, while light of all other qualities, even though very nearly agreeing with them, is transmitted with comparatively no loss.

(5) That Fraunhofer's double dark line D of solar and stellar spectra is due to the presence of vapour of sodium in atmospheres surrounding the sun and those stars in whose spectra it had been observed.

(6) That other vapours than sodium are to be found in the atmospheres of sun and stars by searching for substances producing in the spectra of artificial flames bright lines coinciding with other dark lines of the solar and stellar spectra than the Fraunhofer line D.

The last of these propositions I felt to be confirmed (it was perhaps partly suggested) by a striking and beautiful experiment admirably adapted for lecture illustrations, due to Foucault, which had been shown to me by M. Duboscque Soleil, and the Abbé Moigno, in Paris in the month of October 1850. A prism and lenses were arranged to throw upon a screen an approximately pure spectrum of a vertical electric arc between charcoal poles of a powerful battery, the lower one of which was hollowed like a cup. When pieces of copper and pieces of zinc were separately thrown into the cup, the spectrum exhibited, in perfectly definite positions, magnificent well-marked bands of different colours characteristic of the two metals. When a piece of brass, compounded of copper and zinc, was put into the cup, the spectrum showed all the bands, each precisely in the place in which it had been seen when one metal or the other had been used separately.

It is much to be regretted that this great generalization was not published to the world twenty years ago. I say this, not because it is to be regretted that Ångström should have the credit of having in 1853 published independently the statement that "an incandescent gas emits luminous rays of the same refrangibility as those which it can absorb"; or that Balfour Stewart should have been unassisted by it when, coming to the subject from a very different point of view, he made, in his extension of the "Theory of Exchanges"*, the still wider generalization that the radiating power of every kind of substance is equal to its absorbing power for every kind of ray; or that Kirchhoff also should have in 1859 independently discovered the same proposition, and shown its application to solar and stellar chemistry; but because we might now be in possession of the inconceivable riches of astronomical results which we expect from the next ten years' investigation by spectrum analysis, had Stokes given his theory to the world when it first occurred to him.

To Kirchhoff belongs, I believe, solely the great credit of having first

* Edin. Transactions, 1858–59.

actually sought for and found other metals than sodium in the sun by the method of spectrum analysis. His publication of October 1859 inaugurated the practice of solar and stellar chemistry, and gave spectrum analysis an impulse to which in a great measure is due its splendidly successful cultivation by the labours of many able investigators within the last ten years.

To prodigious and wearing toil of Kirchhoff himself, and of Ångström, we owe large-scale maps of the solar spectrum, incomparably superior in minuteness and accuracy of delineation to any thing ever attempted previously. These maps now constitute the standards of reference for all workers in the field. Plücker and Hittorf opened ground in advancing the physics of spectrum analysis and made the important discovery of changes in the spectra of ignited gases produced by changes in the physical condition of the gas. The scientific value of the meetings of the British Association is well illustrated by the fact that it was through conversation with Plücker at the Newcastle meeting that Lockyer was first led into the investigation of the effects of varied pressure on the quality of the light emitted by glowing gas which he and Frankland have prosecuted with such admirable success. Scientific wealth tends to accumulation according to the law of compound interest. Every addition to knowledge of properties of matter supplies the naturalist with new instrumental means for discovering and interpreting phenomena of nature, which in their turn afford foundations for fresh generalizations, bringing gains of permanent value into the great storehouse of philosophy. Thus Frankland, led, from observing the want of brightness of a candle burning in a tent on the summit of Mont Blanc, to scrutinize Davy's theory of flame, discovered that brightness without incandescent solid particles is given to a purely gaseous flame by augmented pressure, and that a dense ignited gas gives a spectrum comparable with that of the light from an incandescent solid or liquid. Lockyer joined him; and the two found that every incandescent substance gives a continuous spectrum—that an incandescent gas under varied pressure gives bright bars across the continuous spectrum, some of which, from the sharp, hard and fast lines observed where the gas is in a state of extreme attenuation, broaden out on each side into nebulous bands as the density is increased, and are ultimately lost in the continuous spectrum when the condensation is pushed on till the gas becomes a fluid no longer to be called gaseous. More recently they have examined the influence of temperature, and have obtained results which seem to show that a highly attenuated gas, which at a high temperature gives several bright lines, gives a smaller and smaller number of lines, of sufficient brightness to be visible, when the temperature is lowered, the density being kept unchanged. I cannot refrain here from remarking how admirably this beautiful investigation harmonizes with Andrews' great discovery of continuity between the gaseous and liquid states. Such things make the life-blood of science. In contemplating them we feel as if led out from narrow waters of scholastic dogma to a refreshing excursion on the broad and deep ocean of truth, where we learn from the wonders we see that there are endlessly more and more glorious wonders still unseen.

Stokes' dynamical theory supplies the key to the philosophy of Frankland and Lockyer's discovery. Any atom of gas when struck and left to itself vibrates with perfect purity its fundamental note or notes. In a highly attenuated gas each atom is very rarely in collision with other atoms, and therefore is nearly at all times in a state of true vibration. Hence the spectrum of a highly attenuated gas consists of one or more perfectly sharp bright lines, with a scarcely perceptible continuous gradation

of prismatic colour. In denser gas each atom is frequently in collision, but still is for much more time free, in intervals between collisions, than engaged in collision; so that not only is the atom itself thrown sensibly out of tune during a sensible proportion of its whole time, but the confused jangle of vibrations in every variety of period during the actual collision becomes more considerable in its influence. Hence bright lines in the spectrum broaden out somewhat, and the continuous spectrum becomes less faint. In still denser gas each atom may be almost as much time in collision as free, and the spectrum then consists of broad nebulous bands crossing a continuous spectrum of considerable brightness. When the medium is so dense that each atom is always in collision, that is to say never free from influence of its neighbours, the spectrum will generally be continuous, and may present little or no appearance of bands, or even of maxima of brightness. In this condition the fluid can be no longer regarded as a gas, and we must judge of its relation to the vaporous or liquid states according to the critical conditions discovered by Andrews.

While these great investigations of properties of matter were going on, naturalists were not idle with the newly recognized power of the spectroscope at their service. Chemists soon followed the example of Bunsen in discovering new metals in terrestrial matter by the old blow-pipe and prism test of Fox Talbot and Herschel. Biologists applied spectrum analysis to animal and vegetable chemistry, and to sanitary investigations. But it is in astronomy that spectroscopic research has been carried on with the greatest activity, and been most richly rewarded with results. The chemist and the astronomer have joined their forces. An astronomical observatory has now, appended to it, a stock of reagents such as hitherto was only to be found in the chemical laboratory. A devoted corps of volunteers of all nations, whose motto might well be *ubique,* have directed their artillery to every region of the universe. The sun, the spots on his surface, the corona and the red and yellow prominences seen round him during total eclipses, the moon, the planets, comets, auroras, nebulæ, white stars, yellow stars, red stars, variable and temporary stars, each tested by the prism was compelled to show its distinguishing colours. Rarely before in the history of science has enthusiastic perseverance directed by penetrative genius produced within ten years so brilliant a succession of discoveries. It is not merely the *chemistry* of sun and stars, as first suggested, that is subjected to analysis by the spectroscope. Their whole laws of being are now subjects of direct investigation; and already we have glimpses of their evolutional history through the stupendous power of this most subtle and delicate test. We had only solar and stellar chemistry; we now have solar and stellar physiology.

It is an old idea that the colour of a star may be influenced by its motion relatively to the eye of the spectator, so as to be tinged with red if it moves from the earth, or blue if it moves towards the earth. William Allen Miller, Huggins, and Maxwell showed how, by aid of the spectroscope, this idea may be made the foundation of a method of measuring the relative velocity with which a star approaches to or recedes from the earth. The principle is, first to identify, if possible, one or more of the lines in the spectrum of the star, with a line or lines in the spectrum of sodium, or some other terrestrial substance, and then (by observing the star and the artificial light simultaneously by the same spectroscope) to find the difference, if any, between their refrangibilities. From this difference of refrangibility the ratio of the periods of the two lights is calculated, according to data determined by Fraunhofer from

comparisons between the positions of the dark lines in the prismatic spectrum and in his own "interference spectrum" (produced by substituting for the prism a fine grating). A first comparatively rough application of the test by Miller and Huggins to a large number of the principal stars of our skies, including Aldebaran, α Orionis, β Pegasi, Sirius, α Lyræ, Capella, Arcturus, Pollux, Castor (which they had observed rather for the chemical purpose than for this), proved that not one of them had so great a velocity as 315 kilometres per second to or from the earth, which is a *most momentous result in respect to cosmical dynamics.* Afterwards Huggins made special observations of the velocity test, and succeeded in making the measurement in one case, that of Sirius, which he then found to be receding from the earth at the rate of 66 kilometres per second. This, corrected for the velocity of the earth at the time of the observation, gave a velocity of Sirius, relatively to the Sun, amounting to 47 kilometres per second. The minuteness of the difference to be measured, and the smallness of the amount of light, even when the brightest star is observed, renders the observation extremely difficult. Still, with such great skill as Mr. Huggins has brought to bear on the investigation, it can scarcely be doubted that velocities of many other stars may be measured. What is now wanted is, certainly not greater skill, perhaps not even more powerful instruments, but *more instruments and more observers.* Lockyer's applications of the velocity test to the relative motions of different gases in the Sun's photosphere, spots, chromosphere, and chromospheric prominences, and his observations of the varying spectra presented by the same substance as it moves from one position to another in the Sun's atmosphere, and his interpretations of these observations, according to the laboratory results of Frankland and himself, go far towards confirming the conviction that in a few years all the marvels of the Sun will be dynamically explained according to known properties of matter.

During six or eight precious minutes of time, spectroscopes have been applied to the solar atmosphere and to the corona seen round the dark disk of the Moon eclipsing the Sun. Some of the wonderful results of such observations, made in India on the occasion of the eclipse of August 1868, were described by Professor Stokes in a previous address. Valuable results have, through the liberal assistance given by the British and American Governments, been obtained also from the total eclipse of last December, notwithstanding a generally unfavourable condition of weather. It seems to have been proved that at least some sensible part of the light of the "corona" is a terrestrial atmospheric halo or dispersive reflection of the light of the glowing hydrogen and "helium"* round the sun. I believe I may say, on the present occasion when preparation must again be made to utilize a total eclipse of the Sun, that the British Association confidently trusts to our Government exercising the same wise liberality as heretofore in the interests of science.

The old nebular hypothesis supposes the solar system, and other similar systems through the universe which we see at a distance as stars, to have originated in the condensation of fiery nebulous matter. This hypothesis was invented before the discovery of thermo-dynamics, or the nebulæ would not have been supposed to be fiery; and the idea seems never to have occurred to any of its inventors or early supporters that the matter, the condensation of which they supposed to constitute the Sun and stars, could have

* Frankland and Lockyer find the yellow prominences to give a very decided bright line not far from D, but hitherto not identified with any terrestrial flame. It seems to indicate a new substance, which they propose to call Helium.

been other than fiery in the beginning. Mayer first suggested that the heat of the Sun may be due to gravitation: but he supposed meteors falling in to keep always generating the heat which is radiated year by year from the Sun. Helmholtz, on the other hand, adopting the nebular hypothesis, showed in 1854 that it was not necessary to suppose the nebulous matter to have been originally fiery, but that mutual gravitation between its parts may have generated the heat to which the present high temperature of the Sun is due. Further he made the important observations that the potential energy of gravitation in the Sun is even now far from exhausted; but that with further and further shrinking more and more heat is to be generated, and that thus we can conceive the Sun even now to possess a sufficient store of energy to produce heat and light, almost as at present, for several million years of time future. It ought, however, to be added that this condensation can only follow from cooling, and therefore that Helmholtz's gravitational explanation of future Sun-heat amounts really to showing that the Sun's thermal capacity is enormously greater, in virtue of the mutual gravitation between the parts of so enormous a mass, than the sum of the thermal capacities of separate and smaller bodies of the same material and same total mass. Reasons for adopting this theory, and the consequences which follow from it, are discussed in an article "On the Age of the Sun's Heat," published in 'Macmillan's Magazine' for March 1862.

For a few years Mayer's theory of solar heat had seemed to me probable; but I had been led to regard it as no longer tenable, because I had been in the first place driven, by consideration of the very approximate constancy of the Earth's period of revolution round the Sun for the last 2000 years, to conclude that "The principal source, perhaps the sole appreciably effective "source of Sun-heat, is in bodies circulating round the Sun at present inside "the Earth's orbit"*; and because Le Verrier's researches on the motion of the planet Mercury, though giving evidence of a sensible influence attributable to matter circulating as a great number of small planets within his orbit round the Sun, showed that the amount of matter that could possibly be assumed to circulate at any considerable distance from the Sun must be very small; and therefore "if the meteoric influx taking place at present is "enough to produce any appreciable portion of the heat radiated away, it "must be supposed to be from matter circulating round the Sun, within very "short distances of his surface. The density of this meteoric cloud would "have to be supposed so great that comets could scarcely have escaped as "comets actually have escaped, showing no discoverable effects of resistance, "after passing his surface within a distance equal to one-eighth of his radius. "All things considered, there seems little probability in the hypothesis that "solar radiation is compensated to any appreciable degree, by heat generated "by meteors falling in, at present; and, as it can be shown that no chemical "theory is tenable†, it must be concluded as most probable that the Sun is "at present mere an incandescent liquid mass cooling"‡.

Thus on purely astronomical grounds was I long ago led to abandon as very improbable the hypothesis that the Sun's heat is supplied dynamically from year to year by the influx of meteors. But now spectrum analysis gives proof finally conclusive against it.

Each meteor circulating round the Sun must fall in along a very gradual

* "On the mechanical energies of the Solar System." Transactions of the Royal Society of Edinburgh, 1854; and Phil. Mag. 1854, second half year.

† "Mechanical Energies" &c.

‡ "Age of the Sun's Heat" (Macmillan's Magazine, March 1862).

spiral path, and before reaching the Sun must have been for a long time exposed to an enormous heating effect from his radiation when very near, and must thus have been driven into vapour before actually falling into the Sun. Thus, if Mayer's hypothesis is correct, friction between vortices of meteoric vapours and the Sun's atmosphere must be the immediate cause of solar heat; and the velocity with which these vapours circulate round equatorial parts of the Sun must amount to 435 kilometres per second. The spectrum test of velocity applied by Lockyer showed but a twentieth part of this amount as the greatest observed relative velocity between different vapours in the Sun's atmosphere.

At the first Liverpool Meeting of the British Association (1854), in advancing a gravitational theory to account for all the heat, light, and motions of the universe, I urged that the immediately antecedent condition of the matter of which the Sun and Planets were formed, not being fiery, could not have been gaseous; but that it probably was solid, and may have been like the meteoric stones which we still so frequently meet with through space. The discovery of Huggins, that the light of the nebulæ, so far as hitherto sensible to us, proceeds from incandescent hydrogen and nitrogen gases, and that the heads of comets also give us light of incandescent gas, seems at first sight literally to fulfil that part of the nebular hypothesis to which I had objected. But a solution, which seems to me in the highest degree probable, has been suggested by Tait. He supposes that it may be by ignited gaseous exhalations proceeding from the collision of meteoric stones that Nebulæ and the heads of comets show themselves to us; and he suggested, at a former meeting of the Association, that experiments should be made for the purpose of applying spectrum analysis to the light which has been observed in gunnery trials, such as those at Shoeburyness, when iron strikes against iron at a great velocity, but varied by substituting for the iron various solid materials, metallic or stony. Hitherto this suggestion has not been acted upon; but surely it is one the carrying out of which ought to be promoted by the British Association.

Most important steps have been recently made towards the discovery of the nature of comets, establishing with nothing short of certainty the truth of a hypothesis which had long appeared to me probable, that they consist of groups of meteoric stones, accounting satisfactorily for the light of the nucleus, and giving a simple and rational explanation of phenomena presented by the tails of comets which had been regarded by the greatest astronomers as almost preternaturally marvellous. The meteoric hypothesis to which I have referred remained a mere hypothesis (I do not know that it was ever even published) until, in 1866, Schiaparelli calculated, from observations on the August meteors, an orbit for these bodies which he found to agree almost perfectly with the orbit of the great comet of 1862 as calculated by Oppolzer; and so discovered and demonstrated that a comet consists of a group of meteoric stones. Professor Newton, of Yale College, United States, by examining ancient records, ascertained that in periods of about thirty-three years, since the year 902, there have been exceptionally brilliant displays of the November meteors. It had long been believed that these interesting visitants came from a train of small detached planets circulating round the Sun all in nearly the same orbit, and constituting a belt analogous to Saturn's ring, and that the reason for the comparatively large number of meteors which we observe annually about the 14th of November is, that at that time the earth's orbit cuts through the supposed meteoric belt. Professor Newton concluded from his investigation that there is a denser part of

the group of meteors which extends over a portion of the orbit so great as to occupy about one-tenth or one-fifteenth of the periodic time in passing any particular point, and gave a choice of five different periods for the revolution of this meteoric stream round the sun, any one of which would satisfy his statistical result. He further concluded that the line of nodes (that is to say, the line in which the plane of the meteoric belt cuts the plane of the Earth's orbit) has a progressive sidereal motion of about 52″·4 per annum. Here, then, was a splendid problem for the physical astronomer; and, happily, one well qualified for the task, took it up. Adams, by the application of a beautiful method invented by Gauss, found that of the five periods allowed by Newton just one permitted the motion of the line of nodes to be explained by the disturbing influence of Jupiter, Saturn, and other planets. The period chosen on these grounds is $33\frac{1}{4}$ years. The investigation showed further that the form of the orbit is a long ellipse, giving for shortest distance from the Sun 145 million kilometres, and for longest distance 2895 million kilometres. Adams also worked out the longitude of the perihelion and the inclination of the orbit's plane to the plane of the ecliptic. The orbit which he thus found agreed so closely with that of Temple's Comet I. 1866 that he was able to identify the comet and the meteoric belt*. The same conclusion had been pointed out a few weeks earlier by Schiaparelli, from calculations by himself on data supplied by direct observations on the meteors, and independently by Peters from calculations by Leverrier on the same foundation. It is therefore thoroughly established that Temple's Comet I. 1866 consists of an elliptic train of minute planets, of which a few thousands or millions fall to the earth annually about the 14th of November, when we cross their track. We have probably not yet passed through the very nucleus or densest part; but thirteen times, in Octobers and Novembers, from October 13, A.D. 902, to November 14, 1866 inclusive (this last time having been correctly predicted by Prof. Newton), we have passed through a part of the belt greatly denser than the average. The densest part of the train, when near enough to us, is visible as the head of the comet. This astounding result, taken along with Huggins's spectroscopic observations on the light of the heads and tails of comets, confirms most strikingly Tait's theory of comets, to which I have already referred; according to which the comet, a group of meteoric stones, is self-luminous in its nucleus, on account of collisions among its constituents, while its "tail" is merely a portion of the less dense part of the train illuminated by sunlight, and visible or invisible to us according to circumstances, not only of density, degree of illumination, and nearness, but also of tactic arrangement, as of a flock of birds or the edge of a cloud of tobacco-smoke! What prodigious difficulties are to be explained, you may judge from two or three sentences which

* Signor Schiaparelli, Director of the Observatory of Milan, who, in a letter dated 31st December 1866, pointed out that the elements of the orbit of the *August* Meteors, calculated from the observed position of their radiant point on the supposition of the orbit being a very elongated ellipse, agreed very closely with those of the orbit of Comet II. 1862, calculated by Dr. Oppolzer. In the same letter Schiaparelli gives elements of the orbit of the November meteors, but these were not sufficiently accurate to enable him to identify the orbit with that of any known comet. On the 21st January, 1867, M. Leverrier gave more accurate elements of the orbit of the November Meteors, and in the 'Astronomische Nachrichten' of January 9, Mr. C. F. W. Peters, of Altona, pointed out that these elements closely agreed with those of Temple's Comet (I 1866), calculated by Dr. Oppolzer; and on February 2, Schiaparelli having recalculated the elements of the orbit of the meteors, himself noticed the same agreement. Adams arrived quite independently at the conclusion that the orbit of $33\frac{1}{4}$ years period is the one which *must* be chosen out of the five indicated by Prof. Newton. His calculations were sufficiently advanced before the letters

I shall read from Herschel's Astronomy, and from the fact that even Schiaparelli seems still to believe in the repulsion. "There is, beyond question, some "profound secret and mystery of nature concerned in the phenomenon of "their tails. Perhaps it is not too much to hope that future observation, "borrowing every aid from rational speculation, grounded on the progress of "physical science generally (especially those branches of it which relate to "the ethereal or imponderable elements), may enable us ere long to penetrate "this mystery, and to declare whether it is really *matter* in the ordinary "acceptation of the term which is projected from their heads with such "extraordinary velocity, and if not *impelled*, at least *directed*, in its course, "by reference to the Sun, as its point of avoidance"*.

"In no respect is the question as to the materiality of the tail more for-"cibly pressed on us for consideration than in that of the enormous sweep "which it makes round the sun *in perihelio* in the manner of a straight and "rigid rod, *in defiance of the law of gravitation*, nay, even, *of the received* laws "of motion"*.

"The projection of this ray . . . to so enormous a length, in a single day, "conveys an impression of the intensity of the forces acting to produce such "a velocity of material transfer through space, such as no other natural phe-"nomenon is capable of exciting. It is clear that *if we have to deal here with* "*matter, such as we conceive it* (viz. *possessing inertia*), *at all*, it must be under "the dominion of forces incomparably more energetic than gravitation, and "quite of a different nature" †.

Think, now, of the admirable simplicity with which Tait's beautiful "sea-bird analogy," as it has been called, can explain all these phenomena.

The essence of science, as is well illustrated by astronomy and cosmical physics, consists in inferring antecedent conditions, and anticipating future evolutions, from phenomena which have actually come under observation. In biology the difficulties of successfully acting up to this ideal are prodigious. The earnest naturalists of the present day are, however, not appalled or paralyzed by them, and are struggling boldly and laboriously to pass out of the mere "Natural History stage" of their study, and bring zoology within the range of Natural Philosophy. A very ancient speculation, still clung to by many naturalists (so much so that I have a choice of modern terms to quote in expressing it), supposes that, under meteorological conditions very different from the present, dead matter may have run together or crystallized or fermented into "germs of life," or "organic cells," or "protoplasm." But science brings a vast mass of inductive evidence against this hypothesis of spontaneous generation, as you have heard from my predecessor in the Presidential chair. Careful enough scrutiny has, in every case up to the present day, discovered life as antecedent to life. Dead matter cannot become living without coming under the influence of matter previously alive. This seems to me as sure a teaching of science as the law of gravitation. I utterly repudiate, as opposed to all philosophical uniformitarianism, the assumption of "different meteorological conditions"—that is to say, somewhat different vicissitudes of temperature, pressure,

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referred to appeared, to show that the other four orbits offered by Newton were inadmissible. But the calculations to be gone through to find the secular motion of the node in such an elongated orbit as that of the meteors were necessarily very long, so that they were not completed till about March 1867. They were communicated in that month to the Cambridge Philosophical Society, and in the month following to the Astronomical Society.

* Herschel's Astronomy, § 599.

† Herschel's Astronomy, 10th edition, § 589.

moisture, gaseous atmosphere—to produce or to permit that to take place by force or motion of dead matter alone, which is a direct contravention of what seems to us biological law. I am prepared for the answer, "our code of "biological law is an expression of our ignorance as well as of our know-"ledge." And I say yes: search for spontaneous generation out of inorganic materials; let any one not satisfied with the purely negative testimony, of which we have now so much against it, throw himself into the inquiry. Such investigations as those of Pasteur, Pouchet, and Bastian are among the most interesting and momentous in the whole range of Natural History, and their results, whether positive or negative, must richly reward the most careful and laborious experimenting. I confess to being deeply impressed by the evidence put before us by Professor Huxley, and I am ready to adopt, as an article of scientific faith, true through all space and through all time, that life proceeds from life, and from nothing but life.

How, then, did life originate on the Earth? Tracing the physical history of the Earth backwards, on strict dynamical principles, we are brought to a red-hot melted globe on which no life could exist. Hence when the Earth was first fit for life, there was no living thing on it. There were rocks solid and disintegrated, water, air all round, warmed and illuminated by a brilliant Sun, ready to become a garden. Did grass and trees and flowers spring into existence, in all the fulness of ripe beauty, by a fiat of Creative Power? or did vegetation, growing up from seed sown, spread and multiply over the whole Earth? Science is bound, by the everlasting law of honour, to face fearlessly every problem which can fairly be presented to it. If a probable solution, consistent with the ordinary course of nature, can be found, we must not invoke an abnormal act of Creative Power. When a lava stream flows down the sides of Vesuvius or Etna it quickly cools and becomes solid; and after a few weeks or years it teems with vegetable and animal life, which for it originated by the transport of seed and ova and by the migration of individual living creatures. When a volcanic island springs up from the sea, and after a few years is found clothed with vegetation, we do not hesitate to assume that seed has been wafted to it through the air, or floated to it on rafts. Is it not possible, and if possible, is it not probable, that the beginning of vegetable life on the Earth is to be similarly explained? Every year thousands, probably millions, of fragments of solid matter fall upon the Earth—whence came these fragments? What is the previous history of any one of them? Was it created in the beginning of time an amorphous mass? This idea is so unacceptable that, tacitly or explicitly, all men discard it. It is often assumed that all, and it is certain that some, meteoric stones are fragments which had been broken off from greater masses and launched free into space. It is as sure that collisions must occur between great masses moving through space as it is that ships, steered without intelligence directed to prevent collision, could not cross and recross the Atlantic for thousands of years with immunity from collisions. When two great masses come into collision in space it is certain that a large part of each is melted; but it seems also quite certain that in many cases a large quantity of débris must be shot forth in all directions, much of which may have experienced no greater violence than individual pieces of rock experience in a land-slip or in blasting by gunpowder. Should the time when this Earth comes into collision with another body, comparable in dimensions to itself, be when it is still clothed as at present with vegetation, many great and small fragments carrying seed and living plants and animals would undoubtedly be scattered through space. Hence and because we all confidently believe that there are at present, and have been from time

immemorial, many worlds of life besides our own, we must regard it as probable in the highest degree that there are countless seed-bearing meteoric stones moving about through space. If at the present instant no life existed upon this Earth, one such stone falling upon it might, by what we blindly call *natural* causes, lead to its becoming covered with vegetation. I am fully conscious of the many scientific objections which may be urged against this hypothesis; but I believe them to be all answerable. I have already taxed your patience too severely to allow me to think of discussing any of them on the present occasion. The hypothesis that life originated on this Earth through moss-grown fragments from the ruins of another world may seem wild and visionary; all I maintain is that it is not unscientific.

From the Earth stocked with such vegetation as it could receive meteorically, to the Earth teeming with all the endless variety of plants and animals which now inhabit it, the step is prodigious; yet, according to the doctrine of continuity, most ably laid before the Association by a predecessor in this Chair (Mr. Grove), all creatures now living on earth have proceeded by orderly evolution from some such origin. Darwin concludes his great work on 'The Origin of Species' with the following words:—"It is interesting to contemplate an entangled bank clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent on each other in so complex a manner, have all been produced by laws acting around us." . . . . "There is grandeur in this view of life with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms, most beautiful and most wonderful, have been and are being evolved." With the feeling expressed in these two sentences I most cordially sympathize. I have omitted two sentences which come between them, describing briefly the hypothesis of "the origin of species by natural selection," because I have always felt that this hypothesis does not contain the true theory of evolution, if evolution there has been, in biology. Sir John Herschel, in expressing a favourable judgment on the hypothesis of zoological evolution (with, however, some reservation in respect to the origin of man), objected to the doctrine of natural selection, that it was too like the Laputan method of making books, and that it did not sufficiently take into account a continually guiding and controlling intelligence. This seems to me a most valuable and instructive criticism. I feel profoundly convinced that the argument of design has been greatly too much lost sight of in recent zoological speculations. Reaction against the frivolities of teleology, such as are to be found, not rarely, in the notes of the learned commentators on Paley's 'Natural Theology,' has I believe had a temporary effect in turning attention from the solid and irrefragable argument so well put forward in that excellent old book. But overpoweringly strong proofs of intelligent and benevolent design lie all round us; and if ever perplexities, whether metaphysical or scientific, turn us away from them for a time, they come back upon us with irresistible force, showing to us through Nature the influence of a free will, and teaching us that all living beings depend on one ever-acting Creator and Ruler.

REPORTS

ON

THE STATE OF SCIENCE.

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Seventh Report of the Committee for Exploring Kent's Cavern, Devonshire,—the Committee consisting of Sir Charles Lyell, *Bart., F.R.S.*, Professor Phillips, *F.R.S.*, Sir John Lubbock, *Bart., F.R.S.*, John Evans, *F.R.S.*, Edward Vivian, George Busk, *F.R.S.*, William Boyd Dawkins, *F.R.S.*, William Aysiford Sanford, *F.G.S., and* William Pengelly, *F.R.S.* (Reporter).

During the year which has elapsed since the Sixth Report was sent in (Liverpool, 1870), the Committee have without intermission carried on their researches, and have strictly followed the mode of working with which the exploration was commenced in 1865. The Superintendents have continued to visit the Cavern, and to record the results daily; they have, as from the beginning, sent Monthly Reports to the Chairman of the Committee; the work has been carried on by the same workmen, George Smerdon and John Farr, who have discharged their duties in a most efficient and satisfactory manner; and the Cavern is as much resorted to as ever by visitors feeling an interest in the researches.

In June 1871, Mr. Busk, a Member of the Committee, spent some time at Torquay, when he visited the Cavern accompanied by the Superintendents, who took him through all its branches, explored and unexplored. Having carefully watched the progress of the work, and made himself familiar with all its details, he spent some time at the Secretary's residence, examining and identifying a portion of the mammalian remains which had been disinterred.

In November 1870 the Superintendents had also the pleasure of going through the cavern with Mr. W. Morrison, M.P., who takes so active an interest in the exploration of the caves near Settle in Yorkshire.

Besides the foregoing, and exclusive of the large number attended by the guide appointed by the proprietor, Sir L. Palk, Bart., M.P., the Cavern has been visited during the year by the Earl and Countess Russell, Sir R. Sinclair, Bart., Sir C. Trevelyan, Mr. C. Gilpin, M.P., Governor Wayland, U.S., Colonel Ward, Major Bryce, U.S., Rev. Mr. Dickenson, Rev. E. N. Dumbleton, Rev. J. P. Foster, Rev. T. R. R. Stebbing, Dr. Ashford, Dr. Tate, and Messrs. S. Bate, R. Bellasis, L. Bowring, W. R. A. Boyle, W. Bridges,

C. Busk, A. Champernowne, Channing, Chaplin, F. A. Fellows, T. Fox, T. Glaisher, J. Harrison, Howard, W. Jones, C. Pannel, Richie, W. Spriggs, E. B. Tawney, G. H. Wollaston, and many others.

Smerdon's Passage.—The Committee stated in their last Report that, in excavating the "North Sally-port," they had been led to a third External Entrance to the Cavern, in the same limestone cliff as the two Entrances known from time immemorial, but at a considerably lower level, where it was completely buried in a great talus of débris. After adding that it had not been thought necessary, or desirable, or even safe to dig through the talus to the open day, they stated the facts which left no doubt of their having penetrated to the outside of the Cavern. During the winter of 1870–71, the question of the existence of the third Entrance was put beyond all doubt; for, after a considerable rainfall, that portion of the talus which the workmen had undermined fell in, and thereby laid open the Entrance. This cavity was at once filled up, in order to prevent any one from intruding into the Cavern.

It was also stated last year that the new or low-level opening was the External Entrance not only of the North Sally-port, but of another and unsuspected branch of the Cavern, to which had been given the name of "Smerdon's Passage," the exploration of which had been begun.

This Passage was found to consist of two *Reaches*, the first, or outermost, being about 25 feet long, from 3 to 10 feet wide, and having a northerly direction. Near its entrance, or southern end, there are in the roof a few circular holes, from 6 to 12 inches in diameter, apparently the mouths of tortuous shafts extending for some distance into, or perhaps through, the limestone rock. The roof itself and the adjacent portions of the wall bear traces of the long-continued *erosive* action of running water, but below the uppermost 12 or 18 inches the walls have many sharp angular inequalities. Further in, the roof has an irregular fretted aspect, apparently the result of the *corrosive* action of acidulated water, whilst the walls retain the angular appearance just mentioned.

The Second Reach runs nearly east and west, is about 32 feet long, somewhat wider than the first, and its roof is several feet higher. At its outer or eastern end the roof and walls are much fretted; further in, there are holes in the roof similar to those just mentioned, with the exception of being larger. Some of them contain a small quantity of soil, resembling Cave-earth, and firmly cemented to the wall; whilst adjacent to others there is a considerable amount of stalactitic matter. Still further in, the roof, which has the aspect of a watercourse, is covered with a thin veneer of white stalactite; and near the inner end there is a considerable hole in the roof containing a large accumulation of the same material.

At the western or inner end of this Second Reach, the limestone roof gave place to one consisting of angular pieces of limestone cemented with carbonate of lime into a very firm concrete. In breaking this up, the workman thrust his iron bar up through it, and found he had thereby opened a passage into the eastern end of that branch of the Cavern known as the "Sloping Chamber," the concrete floor of which was at the same time the roof of the Passage.

At the outer or eastern end of the Second Reach there was found another Low-level Entrance, about 20 feet from that previously mentioned, and having no marks of the action of water.

Narrow ramifications extend through the limestone rock from both Reaches of Smerdon's Passage (westward from the first, and southwards from the

second) and intersect one another; their roofs are also perforated with holes, and exhibit traces of the action of running water.

Throughout both Reaches there were in certain places strips of Stalagmitic Floor extending continuously across from wall to wall, and varying from a quarter of an inch to 6 inches in thickness. The most important of these strips was about 8 feet long. Elsewhere the Cave-earth was either completely bare, or had on it here and there what may be called conical scales of stalagmite, from 3 to 12 inches in diameter at the base, and from 1 to 4 inches in thickness at the centre. From them, and generally near the middle, there not unfrequently rose one or more rudely cylindrical masses of the same material, sometimes 9 inches high, 6 inches in circumference, and locally known as "Cow's Paps." In almost every instance of the kind there depended from the limestone roof, vertically over them, a long, slender, quill-like tube of stalactite, occasionally reaching and uniting with the "Paps." Such tubes occurred also in certain places where there were no "Paps," and in some spots there was quite a forest of them, extending from the roof to the Stalagmitic Floor. Wherever it was possible to excavate the deposit beneath without breaking them, they were left intact. In some cases the Stalagmitic Floor, or the Cave-earth where the latter was bare, reached the roof; and where this was not the case, the unoccupied space was rarely more than a foot in height.

About midway in the Second Reach there was on each wall a remnant of an old floor of stalagmite, about 8 inches above the floor found intact, fully 6 inches thick, about 6 feet in length, and within a few inches of the roof.

The mechanical deposit in the Passage was the ordinary red Cave-earth, in some places sandy, but occasionally a very compact clay. It contained a considerable number of angular fragments of limestone, numerous blocks of old crystalline stalagmite, and a few well-rolled pebbles of quartz, red grit, and flint. The masses of limestone were not unfrequently of considerable size; indeed one of them required to be blasted twice, and another three times, in order to effect their removal; and some of the blocks of stalagmite measured fully 15 cubic feet.

From the entrance of the First Reach to about 10 feet within it, the upper surface of the Cave-earth was almost perfectly horizontal; but from the latter point it rose irregularly higher and higher, until, at the inner end of the Second Reach, the increased height amounted to about 9 feet. There were no tunnels or burrows in the deposit, such as occurred in both the Sally-ports, and were described in the Fifth and Sixth Reports (1869 and 1870). Near the inner end of the Second Reach the Cave-earth adjacent to the walls was cemented into a concrete.

The deposit in the lateral ramifications of the Passage was the same typical Cave-earth, containing blocks of old crystalline stalagmite and angular pieces of limestone, but without any Stalagmitic Floor.

It was stated in the Sixth Report (1870), p. 26, that at the third External Entrance, *i. e.* the first of the low-level series, the deposits were of two kinds—the ordinary Cave-earth, with the usual osseous remains, below; and small angular pieces of limestone, with but little earth and no fossils, above. Materials of precisely the same character, and in the same order, were found at the new low-level Entrance, at the eastern end of the Second Reach of Smerdon's Passage, as already stated.

Besides a large number of bones, portions of bones, and fragments of antlers, a total of fully 2900 teeth were found in the Passage and its rami-

fications, of which 700 were reported at Liverpool*. The remaining 2200, exhumed since the end of August 1870, belonged to different kinds of animals, in the ratios shown in the following list:—

Hyæna	335 per thousand.	Bear	18 per thousand.
Horse	295 ,,	Fox............	12 ,,
Rhinoceros	161 ,,	Lion	6 ,,
"Irish Elk"....	55 ,,	Reindeer	5 ,,
Ox............	35 ,,	Wolf	4 ,,
Deer	27 ,,	Bat	2 ,,
Badger........	22 ,,	Rabbit	1 ,,
Elephant	20 ,,	Dog (?) .. less than	1 ,,

On comparing the foregoing list with those given for the Sally-ports in the Sixth Report (pp. 19 and 24), it will be found to differ from them in containing neither Sheep nor Pig, and in the diminished prevalence of Rabbit and Badger.

Many of the teeth are in fragments of jaws, which have, in most cases, lost their condyles and their inferior borders. They belong to individuals of all ages, from the baby Elephant, whose molar crown was no more than ·8 inch long, and the Hyæna, whose second set had made their appearance before the dislodgement of the first, to the wasted remnant of an adult tooth of the Mammoth, and the canine of the Bear worn quite to the fang.

Many of the bones and teeth are discoloured, a large number are gnawed (generally, no doubt, by the Hyæna, but occasionally by some smaller animal), and a considerable proportion of them, at all levels, are more or less covered with films of stalagmitic matter. On some of the specimens are peculiar markings, produced perhaps by fine rootlets of trees having grown round them. Some marked in this way were found with living rootlets surrounding them.

Coprolitic matter was by no means abundant, only one example of it having been met with in the entire Passage.

In various parts of the Passage considerable heaps of small bones, sometimes agglutinated, were found here and there on the surface, or but little below it. In one instance as many as 8400 were picked out of 120 cubic inches of material.

At the junction of the two Reaches of the Passage, a large ledge or curtain of limestone projected downwards from the roof considerably below the usual level. On the inner or northern side of it there was found a wheelbarrow full of bones, fragments of bones, and teeth, of a considerable variety of animals, all huddled together.

It was stated in the First Report (Birmingham, 1865†) that the Cave-earth was excavated in "Parallels," the length of which was the same as the width of the Chamber &c., where this was not excessive, breadth invariably 1 foot, and depth 4 feet, where this gave the men sufficient height to work in comfort, or 5 feet where it did not; that each parallel was divided into successive horizontal "Levels," a foot in depth; and that each level was subdivided into lengths or "Yards," each 3 feet long and, from what has been stated, a foot square in the section, thus rendering it easy to define and record the position of every object discovered.

Smerdon's Passage and its lateral branches contained 78 "Parallels" of

* See Sixth Report, 1870, p. 27. † See pp. 19, 20.

Cave-earth, and, as it was necessary to excavate to the depth of 5 feet*, a total of 390 separate "foot-levels." The following Table shows the distribution of the teeth of the different kinds of animals in the various "Parallels" and "Levels."

	Hyæna.	Horse.	Rhinoceros.	"Irish Elk."	Ox.	Deer.	Badger.	Elephant.	Bear.	Fox.	Lion.	Reindeer.	Wolf.	Bat.	Rabbit.	Dog?
Parallels	71	68	60	29	43	23	14	27	29	14	11	11	9	1	2	3
1st Levels	44	44	32	10	16	9	11	10	6	3	...	1	1	1	2	
2nd "	53	51	42	11	23	7	2	11	9	5	4	1	2	...	...	1
3rd "	43	37	33	16	13	7	2	9	10	4	6	4	4	...	...	2
4th "	29	28	22	9	13	7	...	5	5	4	2	5	3			
5th "	19	16	10	3	6	3	...	5	4	2	1	3	...			
Total Levels ...	188	176	139	49	71	33	15	40	34	18	13	14	10	1	2	3

By way of explanation, it may be stated that teeth of Hyæna, for example, were found in 71 of the 78 "parallels," at all "levels," and in 188 "foot-levels," or very nearly one half of the total number; and so on for the other kinds of animals.

A glance at the Table shows that, in the case of the most prevalent animals—Hyæna, Horse, and Rhinoceros—their teeth were most frequently met with (not necessarily met with in greatest numbers) in the second "foot-level," below which they were less and less frequent as the level was lower; that the Badger was most frequently met with in the uppermost "foot-level," and never found below the third; that teeth of Lion were not found in the uppermost "level," and occurred most frequently in the third; that those of Wolf did not present themselves in the lowest or fifth "foot-level;" that Bat and Rabbit were restricted to the uppermost "level," the former to one "parallel" and the latter to two; and that the Hyæna had the widest distribution, both as regards "parallels" and "levels."

Twelve Flint flakes and chips were found in the Second Reach of the Passage—3 in the first or uppermost "foot-level," 3 in the second, 3 in the third, and 4 in the fourth; there were none in the First Reach, or in the lateral branches. Compared with the fine specimens met with in previous years in other parts of the Cavern, they are perhaps of but little value. Some of them are rather chert than flint, and with one exception (No. 3554) —a well-designed but roughly finished lanceolate implement—they are all of the prevalent white colour.

In the Second Reach there was also found a lance-shaped bone tool (No. 3428), 2·7 inches long, 1·1 inch broad at the butt end, flat on one face and uniformly convex on the other, reduced to a thin edge all round the margin except at the butt end, where it was cut off sharply but somewhat obliquely, tapering gradually to a rounded point, and ·4 inch in greatest thickness. In short, it closely resembled in form and size many of the lanceolate flint implements of the Cavern series, with the single exception that it was not carinated on the convex face. It was found on October 5th, 1870, in the first "foot-level" of Cave-earth, lying with 6 teeth of Hyæna, 1 of Rhinoceros,

* In two or three "Parallels" it was requisite to go to the depth of 6 feet, in order to pass under the "Curtain" of limestone mentioned above.

1 of Bear, 1 of Horse, 1 of "Irish Elk," 2 jaws of Badger containing four teeth, bones and fragments of bone, some of which were gnawed and some invested with films of stalagmite.

It has been already stated that at its eastern extremity the Second Reach of Smerdon's Passage terminated in a "low-level" External Entrance, filled with true Cave-earth below, above which lay an accumulation of small angular stones with but little earth. In the lower deposit the ordinary mammalian remains were found, including teeth and bones of Hyæna, Horse, Rhinoceros, "Irish Elk," Ox, Elephant, Bear, and Reindeer; but the only thing met with in the materials above was an amber bead, ellipsoidal in form, but somewhat thicker on one side than the other, ·9 inch in greatest diameter and ·5 inch in least, and having at its centre a cylindrical perforation about ·2 inch in diameter.

The excavation of Smerdon's Passage was completed on December 31st, 1870, after very nearly five months having been expended on it. From its prevalent narrowness, the labour in it had been attended with much discomfort; but probably no branch of the Cavern had, on the whole, yielded a larger number of mammalian remains.

Minor Ramifications of the North Sally-port.—It was stated in the Sixth Report (1870)*, that there were one or two ramifications of the North Sally-port which had not been excavated, having been passed intentionally in the progress of the work. To these attention was given on the completion of Smerdon's Passage, and they were taken in the order of their proximity to the "Third External Entrance,"—the first discovered of the low-level series.

The first was a small opening in the east wall of the last Reach of the North Sally-port, having its limestone floor very slightly above the top of the deposit in that Reach. It proved to be a tunnel in the limestone, having a rudely triangular transverse section, from 2·5 to 3 feet in height and breadth, and extending eastwards or outwards towards the hill-side for about 8 feet, where it terminated in material of the same character as that found above the Cave-earth in the first and second low-level External Entrances, from the first of which it was about 12 feet distant. There is no doubt that it is a third of these low-level Entrances, and, to use the time-honoured phraseology in descriptions of Kent's Hole, it may be termed the "Oven" Entrance. It contained but little deposit, and the only noteworthy objects found in it were one tooth of Horse, a few bones and bone fragments, and a grit pebble.

The second of these small lateral branches was in the south wall of the immediately preceding or penultimate Reach of the Sally-port, and was too narrow to admit of being excavated in "Parallels" and "Levels." In it were found 7 teeth of Hyæna, 10 of Horse, 3 of Rhinoceros, 1 of Bear, 1 of Lion, 1 of "Irish Elk," 1 of Ox, 16 of Badger in parts of 4 jaws, 10 of Rabbit in parts of 2 jaws, portion of an antler, a right femur of Beaver, bones and fragments of bone, a bit of charcoal, and a grit pebble. It is noteworthy, perhaps, that the fine specimen of Beaver's jaw mentioned last year† was found about 4 or 5 feet from the femur just named, and in the fourth "foot-level."

The third and last of these lateral ramifications was near that part of the Sally-port termed the "Islands"‡. It yielded 2 teeth of Hyæna, 1 of Horse, 3 of Rhinoceros, 1 of Bear, 3 of "Irish Elk," 4 of Deer, 2 of Badger, 4 of Rabbit, an astragalus of Ox, bones and bone fragments, and, in the uppermost "foot-level," 2 land-shells.

* See p. 25. † See Sixth Report, 1870, p. 24. ‡ Ibid. p. 21.

On January 17th, 1871, the workmen finally and gladly emerged from the labyrinth of low narrow passages in which they had been engaged from day to day from November 13th, 1869, or upwards of 14 months. In this time they had not only excavated and taken to the day the deposits, to the depth of 5 feet, in all the extensive and ramifying branches known as the North Sally-port and Smerdon's Passage, and exhumed cartloads of the remains of various animals, including 5900 of their teeth, as well as 20 flint implements and flakes, but, beyond the first Reach of the Sally-port (27 feet long), they had actually discovered the whole of these branches, including three new entrances to the Cavern itself, and had thus added greatly, not only to the extent of Kent's Hole, but to a knowledge of its structure.

The completion of these branches concluded the excavation, to the depth of 4 feet generally, and 5 feet in some instances, below the Stalagmitic Floor, of the whole of the Eastern Division of the Cavern.

The Cavern Entrances.—Before proceeding to a description of the branch which next engaged attention, it may be of service to devote a few words to the Entrances of the Cavern, of which there are now known to be five (two at a high and three at a low level), all in the eastern side of the hill, and within a horizontal distance of 53 feet. Those at the high-level (known from time immemorial) are about 53 feet apart, almost exactly on the same level, and about 189 feet above mean tide. The most northerly of them is that invariably spoken of in all early descriptions of the Cavern as "The Entrance." Those of the lower series are also at very nearly the same level with one another, but from 18 to 20 feet below the former two. Being lower in the sloping hill-side, they are about 24 feet outside or east of the vertical plane passing through the higher entrances. The most southerly ones in the two series are nearly in the same east and west vertical plane.

In order to distinguish them, they are respectively termed:—

1. "The Entrance,"=the more northerly of the upper series, and, from its form, sometimes termed the "Triangular Entrance." It opens into the "Vestibule."

2. The "Arched Entrance,"=the more southerly of the upper series. It opens into the "Great Chamber."

3. The "First Low-level Entrance,"=the middle one of the lower series—the first discovered. It opens into the "North Sally-port" and the "First Reach of Smerdon's Passage."

4. The "Second Low-level Entrance,"=the most northerly of the lower series—the second discovered. It opens into the "Second Reach of Smerdon's Passage."

5. The "Oven Entrance,"=the most southerly of the lower series—the last discovered. It opens into the "North Sally-port."

The Sloping Chamber.—That branch of the Cavern termed the "Sloping Chamber" by Mr. M'Enery was, prior to the Committee's exploration of the "Great Chamber," the largest apartment in it, and is still, perhaps, more calculated than any other to impress visitors. It is the only connexion of the two great divisions of the Cavern, and measures 80 feet from east to west, 25 in greatest breadth, and, since the excavation of its deposits to the depth of 4 feet below the base of the Stalagmitic Floor, 25 in greatest height. Its name was derived from its floor, which, from 20 feet from its eastern side, sloped rapidly towards its western side, falling as much as 14 feet in 60, or at an average angle of 13°·5. Its ceiling sloped more rapidly still, being, as already stated, 25 feet high near the eastern wall, but not more than 6 feet at the western. This ceiling, though representing the

dip of the limestone strata in a general way, is extremely rugged,—here retreating into deep cavities whence huge masses of limestone have fallen, and there ornamented with numerous and heavy masses of Stalactite. Indeed the finest Stalactites in the Cavern occur in it; and one known as the "Chandelier" has always been much admired. A very strong light is required, however, to bring out all the features of the ceiling.

During the autumn of 1866, the upper, or eastern, or level portion of this Chamber was explored, and the results were described in the Third Report (Dundee, 1867). Mr. M'Enery, too, had made extensive, no doubt his most extensive, diggings near the foot of the incline, where he "succeeded in sinking a shaft to the depth of 30 feet at the bottom of the slope, with the view of reaching the original floor"*, which, however, was not realized. Having broken the floor for his shaft, and finding the work very laborious, he availed himself of the opening thus made to extend his diggings eastward, keeping just beneath the floor, which he left spanning his broken ground like an arch.

As it was obvious that a very considerable amount of deposit still remained intact, it was decided, on the completion of Smerdon's Passage, to resume the excavation, not only in the hope of obtaining some of the palæontological treasures with which, according to Mr. M'Enery, the Chamber abounded, but also as a pre-requisite to the exploration of the "Wolf's Den" and the "Long Arcade," into which it opened on the north and south respectively.

The uppermost deposit, as in the adjacent parts of the Cavern, was the Black Mould so frequently mentioned in all previous Reports; and as the Chamber was the only capacious apartment near *the* Entrance, and the only road to the Western Division of the Cavern, which, from some cause, seems to have been more attractive than the Eastern to visitors in, at least, all recent times†, it might have been expected that many comparatively modern objects of interest would have been found in the Mould. In reality, however, such objects were by no means abundant—a fact which may be explicable, perhaps, on the hypothesis that they had been collected by Mr. M'Enery and other early explorers. The only things found in this deposit (which, it may be stated, was of inconsiderable depth) were shells of cockle, limpet, and pecten; two potsherds—one black and of coarse clay, the other brown, in which the clay was finer; a flint chip and a core of the same material; a spindle-whorl of fine-grained micaceous grit, 1·5 inch in diameter, ·5 inch in thickness, and having its external edges rounded off; and a bone awl, 3·7 inches long, ·7 inch broad at the butt end, and partially covered with a film of stalagmite.

Beneath the Black Mould came the ordinary floor of granular and laminated stalagmite, in which, as well as in the deposit beneath, the rugged character of the ceiling suggested that a considerable number of large masses of limestone would be found. Their presence in the floor, moreover, was indicated by the nature of its upper surface, which, though a continuous sheet, with one exception to be noticed hereafter, was so very uneven as to induce an early guide to the Cavern to confer on it the appellation of the "Frozen Billows." Accordingly, the Floor proved to be, with an excep-

* See Trans. Devon. Assoc. vol. iii. p. 248 (1869).

† The following fact seems to be confirmatory on this point:—There are in the various branches of the Western Division (sometimes in places of difficult access) numerous initials and dates on the limestone walls and on bosses of stalagmite—some engraved, some smoked, and some merely chalked—while there are extremely few in the Eastern Division.

tion here and there, a brecciated mass composed of large and small pieces of limestone and blocks of the well-known old crystalline stalagmite, all cemented together and covered with a sheet of the cementing material.

Near the upper part of the slope, and on its southern margin, a space about 14 feet long and varying from 3 to 12 feet broad was without any trace of floor, but occupied with large loose pieces of limestone. Elsewhere the sheet was perfectly continuous until reaching the area in which Mr. M'Enery had dug his shaft. The Floor commonly measured from 12 to 30 inches in thickness, but adjacent to the southern wall it was fully 3 feet, and contained few or no stones.

On being broken into small pieces and carefully examined, it was found to contain 2 teeth of Horse, a portion of a jaw, 2 bones, and half of a fractured flint nodule. About 30 feet down the slope, a series of dark parallel lines were observed in the Floor, the uppermost being about 2 inches below the upper surface. On the advance of the work, they proved to be continuous downward, and to have a greater and greater thickness of stalagmite over them. On careful examination, it was found that each represented what for a time had been the upper surface of the Stalagmitic Floor of the Chamber, and was due to the presence of comminuted charcoal and other dark-coloured extraneous matter. Such a "charcoal streak" also occurred, according to Mr. M'Enery, in the "Long Arcade," within a few feet of the same spot*. The workmen were directed to detach a specimen of the Floor where the streaks were well displayed, and in doing so were so fortunate as to make their fracture at a place where a large cockle-shell lay firmly imbedded in the lowest streak, at a depth of about 8 inches below the surface. Whilst splitting up the Stalagmite on May 16th, 1871, two specimens of well-marked fern-impressions were found in it, about 3 inches below the surface. Nothing of the kind had ever been noticed before.

Below the Stalagmite, as usual, lay the Cave-earth, in which, as was anticipated, pieces of limestone were unusually abundant. Some of them measured several feet in length and breadth, and were fully 2 feet thick. There were also numerous blocks of the old crystalline stalagmite, measuring in some instances upwards of 4 cubic yards, and not unfrequently projecting from the Cave-earth into the overlying granular floor. Though they were carefully broken up, nothing was found in them.

In that portion of the Cave-earth which was found intact, there occurred, as usual, remains of the ordinary Cave-mammals, including about 550 teeth, which may be apportioned as in the following list:—

Hyæna	39	per cent.	Reindeer	2	per cent.
Horse	28·5	,,	Ox	2	,,
Rhinoceros	14	,,	Elephant	1·5	,,
Deer	4	,,	Lion	1	,,
"Irish Elk"	2·5	,,	Wolf	1	,,
Bear	2·5	,,	Dog (?) only one tooth.		

It is, perhaps, worthy of remark that though wild animals still frequent Kent's Hole, and there is reason to believe that some of them have in recent times carried in the bones of others on which they preyed, though the Sloping Chamber is near and between the two high-level Entrances, though the Floor was broken up and thus gave the readiest access to the Cave-earth, and though Mr. M'Enery discontinued his labours upwards of 40 years ago, of which more than 30 were years of quietude in the Cavern, there is in the

* See Trans. Devon. Assoc. vol. iii. pp. 236, 261, 262 (1869).

foregoing list not only neither Sheep nor Pig, but neither Badger, Rabbit, Hare, nor Vole, all of which have been found in other branches, in deposits accessible to burrowing animals.

In the Cave-earth there were also found 52 flint implements, flakes, and chips,—3 of them in the first or uppermost foot-level, 16 in the second, 15 in the third, and 18 in the fourth or lowest. Though none of them are equal to the best the Cavern has yielded in previous years, there are some good lanceolate implements amongst them.

No. 3693 is of light brown translucent flint, 1·85 inch in length, ·9 inch in greatest breadth, ·175 inch in greatest thickness, nearly flat on one side, and carinated on the other. It was found with a few bones in the first foot-level, amongst loose stones, where there was no Stalagmitic Floor over it; hence it may be doubted whether it belongs to the Palæolithic series—a doubt strengthened by the modern aspect of the implement.

No. 3754, of the usual white flint, is 4·2 inches long, ·9 inch in greatest breadth, ·3 inch in greatest thickness, both longitudinally and transversely concave on one side, has a medial ridge on the other, from which, at about an inch from one end, a second ridge proceeds, and has a thin but uneven edge. It was probably pointed at each end, but has unfortunately been broken at one of them. It was found on March the 6th, 1871, in the second foot-level, with splinters of bone, beneath a Stalagmitic Floor 18 inches thick.

No. 5430, also of white flint, is somewhat irregular in form, but may be termed rudely lanceolate; it is 2·7 inches in length, 1·5 inch in extreme breadth, ·3 inch in greatest thickness, slightly concave on one face and irregularly convex on the other. It was found on March 30th, 1871, with 2 teeth of Horse, 1 of Hyæna, and fragments of bone, in the second "foot-level," without any Stalagmitic Floor over it.

No. 3732, a whitish flint, is 2·3 inches long, 1·1 inch in breadth, which is nearly uniform from end to end, slightly concave on one face, convex on the other, on which there are three slight, parallel, longitudinal ridges, sharply truncated at both ends, but primarily thin at the sides. It was found on February 27th, 1871, in the third "foot-level," with a tooth of Hyæna and fragments of bone, without any Stalagmitic Floor over it.

No. 5435, a slightly mottled white flint, is 2·1 inches long, 1·1 inch broad, ·4 inch in greatest thickness, flat on one face, strongly ridged on the other, abruptly truncated at one end, but thin everywhere else, and retains its width almost to the opposite end, which is bluntly rounded. It was found on 31st March, 1871, with a portion of Deer's jaw and fragments of bone, in the third "foot-level," beneath a Stalagmitic Floor, 2 feet thick.

No. 3687, a mottled flint with white prevailing, is 2·6 inches long, 1·2 inch in greatest breadth, ·3 inch in greatest thickness, broadest near the middle, whence it tapers in both directions, somewhat pointed at one end but not at the other, nearly flat on one face and convex on the other, on which there are two ridges—one subcentral and the other nearly marginal. It was found on February 7th, 1871, in the fourth or lowest foot-level, with 1 tooth of Horse, 1 of Hyæna, and a fragment of bone, without any Stalagmitic Floor over it.

No. 5475 so closely resembles No. 3732, mentioned above, as to need no further description. It was found February 27th, 1871, with 1 tooth of Hyæna and fragments of bone, in the fourth "foot-level," but had no Stalagmitic Floor over it.

In this connexion may be mentioned a piece of calcareous spar, which

appears to have been used as a polishing-stone. It was found March 8th, 1871, with 2 teeth of Hyæna, 2 of Horse, 3 of Rhinoceros, gnawed bones, and a flint flake, in the fourth "foot-level," having over it a Stalagmitic Floor 18 inches thick. No such specimen had been noticed before.

A piece of burnt bone was found on the 22nd of the same month, with fragments of bone and fæcal matter, in the second "foot-level," having a Stalagmitic Floor over it.

Mr. M'Enery appears to have excavated beyond the limits of his shaft, not only in an easterly direction, as has been already stated, but also, at least, north and south of it. So far as can be determined, the shaft was first sunk, and the material taken out lodged between it and the western wall of the Chamber, after which he undertook what may be called the adjacent horizontal diggings, and filled up the shaft with a portion of the excavated matter, thereby rendering it impossible to determine the exact site of the shaft itself. He does not appear to have taken outside the Cavern any portion of the deposit in order to ensure its more complete examination; hence it is not probable that all its contents were detected. Indeed, when speaking of his researches in this Chamber, he says, "It was feared that in the ardour of the first search, facts of importance might have been overlooked. The mass of mould thrown up on the former occasion was therefore a second time turned over and carefully searched, but nothing new was brought to light"*.

This mass the Superintendents decided on taking out of the Cavern, partly to facilitate the excavation of deposits certainly intact beyond, and also because it was thought likely to be lodged on unbroken ground. Though there seemed but little prospect of finding any thing by subjecting it to a third search, such a search was nevertheless made, and did not go unrewarded. The heap, though mainly of Cave-earth, included fragments of the granular Stalagmitic Floor and portions of the Black Mould, and yielded hundreds of bones and portions of bones (one having an artificial hole lined with stalagmitic matter), fragments of antlers, the largest fragment of an Elephant's tusk that the Committee have met with, 143 teeth of Hyæna, 153 of Horse, 45 of Rhinoceros, 27 of Deer, including "Irish Elk" and Reindeer, 6 of Bear, 5 of Ox, 5 of Sheep, 3 of Elephant, 3 of Wolf, 3 of Dog (?), 2 of Fox, 2 of Pig, and 1 of Lion, a few marine shells, several fragments of black pottery, 4 pieces of stalagmite with fern-impressions, and 13 flint implements and flakes,—all, with one exception, of the prevalent white colour, and two of them decidedly good specimens of the strongly ridged lanceolate forms. In short, the virgin soil, in some parts of the Cavern, has been less productive than was this mass which had been twice carefully searched, but by candle-light only.

As was thought probable, the mass of dislodged materials proved to be lying on ground which had never been broken. Between Mr. M'Enery's shaft and the west wall of the Chamber there was a space of at least 17 feet; and at 14 feet from the wall the Cave-earth was found to have not only the ordinary granular Stalagmitic Floor overlying it, but to be deposited on another and necessarily an older Floor of the same material, but which, instead of being granular, was made up of prismatic crystals—possessing, in short, the characters both of position and structure of the Old Crystalline Floor found in the "Lecture Hall" and "South-west Chamber," and described in the Fourth Report (Norwich, 1868),—a remnant, *in situ*, of the Floor which had furnished the large blocks of stalagmite found in the Cave-

* See Trans. Devon. Assoc. vol. iii. p. 289 (1869).

earth in the Sloping Chamber, as already stated. From the point where it was first seen, it was everywhere continuous up to the western wall. Its thickness has not been ascertained; for though it was partially broken up in cutting the four-feet section, the bottom of it was not reached. No objects of any kind were found in it. Had Mr. M'Enery's excavations been carried but a yard further west he must have encountered it, and would have been enabled to solve the problem of the blocks which he so often found in the Cave-earth.

The Committee are most anxious to guard against the impression that, in any of the foregoing remarks, they have been unmindful of the service which Mr. M'Enery rendered to science, or have the most remote wish to depreciate the value of his long-continued labours. Indeed, when they remember that the means at his disposal must have been very limited, and that he was amongst the pioneers in cavern searching, they cannot but feel that the extent and results of his investigations are richly entitled to the warmest praise.

They venture, however, to take this opportunity of stating that, in order to a thorough and satisfactory investigation, cavern-deposits should be excavated, not by sinking occasional shafts, but continuously in a horizontal direction, to a uniform depth not exceeding 5 or at most 6 feet at first; that the material should be carefully examined *in situ*, and then taken to daylight for re-examination. Through not following the first, Mr. M'Enery failed to understand the exact historical order of the Cavern-deposits; and through not being able to accomplish the second, he passed over many specimens calculated to have modified his conclusions, and which he would have been delighted to have found. For example, when speaking of the Sloping Chamber, he says, "The [Stalagmitic] crust is thickest in the middle . . . . for opening the excavation, the same means were employed as to break up a mass of ancient masonry. Flint blades were detected in it at all depths, even so low as to come in contact with the fossil bones and their earthy matrix, but never below them" *. During the last six months, however, the excavations made in the same Chamber, and in the immediate neighbourhood of his, have brought forth Flint implements from every level of the Cave-earth to which the work has been carried, and they were actually found in greatest numbers in the lowest levels. To this may be added the fact that in his heap of refuse-matter, which he had twice examined, there were, as has been already said, upwards of a dozen flint blades, such as he stated never occurred *in* the Cave-earth. Had the soil been examined in daylight, they could not have been overlooked; for, instead of being specimens of little value, they are better far than some of those which he figured; and it is but right to add that many of those found by the Committee were thus detected.

Again, Mr. M'Enery was keenly watchful for extraneous objects in the Stalagmitic Floor; and, from his silence on the question, it may be safely concluded that he never saw fern-impressions in it; nevertheless his refuse-heap contained four small slabs of the floor, in each of which was a well-marked impression, requiring not additional manipulation, but simple daylight for their detection. Indeed every specimen of this kind has been recognized outside the Cavern only.

The four slabs just mentioned, as well as the two found by the Committee in the Floor they broke up, have been submitted to Mr. W. Carruthers,

* See Trans. Devon. Assoc. vol. iii. p. 247 (1869).

F.R.S., of the British Museum, who has kindly furnished the following note respecting them:—

"British Museum, 10 July, 1871.

"The ferns are specimens of *Pteris aquilina*, Linn., and have belonged to very luxuriant plants; they do not differ from those now growing in England. It is possible that the fragment $\frac{2}{5497}$ may be another species, but it is too imperfect to determine, and it may only be a barren portion of the *Pteris*, with shorter and broader pinnules than the other specimens.

(Signed) "WM. CARRUTHERS."

Returning for a moment to the Old Crystalline Stalagmitic Floor beneath the Cave-earth, it was observed that, like the modern and granular one, it had here and there on its upper surface conical bosses rising above its general level, and that there were corresponding protuberances vertically above them on the upper floor. The same fact had been noticed in the other branches of the Cavern where the two Floors occurred in the same vertical sections,—a fact apparently warranting the conclusion that the drainage through the Cavern-roof underwent no important change during the entire period represented by the two floors and the intervening Cave-earth. When to this it is added that such bosses are, at least in most cases, vertically beneath Stalactitic pendants on the ceiling, it may be further inferred that the ancient and modern lines of drainage are, in the main, identical.

On the completion of the work in the Sloping Chamber, on July 11, 1871, the excavation of the "Wolf's Den," which opens out of its northern side, was begun. It was in this Den that Mr. M'Enery found the canines of *Machairodus latidens*, which have excited so much attention. No such specimens have been met with during the present investigation up to this time.

The Committee, believing it possible that the subject might prove to be connected with their researches, have from time to time mentioned the occasional occurrence of living animals in the Cavern*. Indeed, Kent's Hole is not better known to the palæontologist as a store-house of mammalian remains, than to the Devonshire naturalist as a home of the Great Horseshoe Bat (*Rhinolophus ferrum-equinum*, Leach); and every visitor, before the present exploration, must have frequently seen them hanging from the walls of the more retired branches. The following facts have presented themselves during the last twelve months:—

Whilst the excavation of one of the lateral branches of Smerdon's Passage was in progress, a considerable number of fresh spindle-shaped fæces, about ·6 inch long and ·2 inch thick, were observed lying on the surface of the Cave-earth, while between it and the roof there was an interspace just sufficient to allow an animal about the size of a Badger to pass.

The workmen having observed that the candles were much nibbled during their absence, that the greasy wooden candlesticks were sometimes carried off and some of them, after a few days, found secreted in small holes, set a suitably baited gin for the suspected offender. Their efforts were rewarded the next morning by finding a rat dead in the trap.

Old newspapers &c. are occasionally sent to the Cavern for the purpose of wrapping up small boxes of specimens, or such delicate objects as need more than ordinary care. On November 28th, 1871, the workmen, using in this way a part of a copy of the 'Saturday Review,' unintentionally left one complete and sound sheet, *i. e.* two leaves, near the spot where they had been at work.

* See Reports Brit. Assoc. 1869, p. 204, and 1870, p. 27.

The next morning they found the paper precisely where they had left it, but with about one-fifth of one of the leaves gone, and the broken margin of the remainder apparently nibbled. There was nothing to prevent the whole from being taken off, and it was noted that, though left in a precarious position, it had not fallen down. The broken leaf was then torn off and preserved, whilst the unbroken one was allowed to remain as a further experiment. The next morning no trace of it was to be seen. That evening a rat-trap was set at the spot, and very near it another leaf of paper was placed, having on it a small stone, which it was supposed a rat, but not a smaller animal, might be capable of moving. The next morning the paper was found where it had been put, but very much nibbled, whilst the trap and the grease with which it was baited appeared to have not been touched. Before leaving work, the men baited the trap with a tempting end of candle, and placed it *on* a leaf of paper; whilst another leaf, weighted with a lump of earth, was placed near. On the following morning both pieces of paper were found to be considerably eaten or torn; and it was noted that the injury done to the former was within the margin of the trap placed on it, whilst the trap itself, as well as its bait, remained unaffected, further than that there were on it a few spindle-shaped fæces about a quarter of an inch long. There can be no doubt that some animal, probably smaller than a rat, carried off the missing leaf to a recess in the Cavern, where it may serve to make its nest comfortable, and perhaps hereafter to puzzle a cavern searcher who may discover it.

Fourth Report of the Committee for the purpose of investigating the rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by Prof. EVERETT, *at the request of the Committee, consisting of* Sir WM. THOMSON, *F.R.S.*, Sir CHARLES LYELL, *Bart., F.R.S.*, Prof. J. CLERK MAXWELL, *F.R.S.*, Prof. PHILLIPS, *F.R.S.*, G. J. SYMONS, *F.M.S.*, Dr. BALFOUR STEWART, *F.R.S.*, Prof. RAMSAY, *F.R.S.*, Prof. A. GEIKIE, *F.R.S.*, JAMES GLAISHER, *F.R.S.*, Rev. Dr. GRAHAM, E. W. BINNEY, *F.R.S.*, GEORGE MAW, *F.G.S.*, W. PENGELLY, *F.R.S.*, S. J. MACKIE, *F.G.S.*, EDWARD HULL, *F.R.S.*, *and* Prof. EVERETT, *D.C.L.* (Secretary).

IN last year's Report, the intention was expressed of boring down at the bottom of Rosebridge Colliery, if the Association would provide the necessary funds. The circumstances were exceptionally inviting, and the Association very liberally granted the sum asked. The Secretary thereupon paid two visits to Rosebridge, descended and to some extent explored the colliery, in company with Mr. Bryham, and, after a careful study of the plans and sections, agreed upon a particular spot where the bore was to be sunk. Tracings of the plans and sections were kindly sent by Mr. Bryham, who in every way cooperated most cordially, and gave much valuable assistance in arranging the scheme of operations. Several weeks elapsed, which were occupied in making and testing a very large spirit thermometer, suitable for reading in the bad light of a mine, and capable of being read, by estimation,

to the hundredth of a degree, from 90° to 110° F.; and on the 7th November the Secretary wrote to Mr. Bryham requesting him to commence operations. Unfortunately, during this brief interval, circumstances had changed. In a neighbouring pit, where the workings were in the same seam of coal as at Rosebridge, though less deep by 200 yards, a considerable quantity of water was found in sinking into the strata underlying this seam. This was a very unexpected circumstance; and as any irruption of water at the bottom of Rosebridge pit, which is now quite dry, would be a most serious affair, Mr. Bryham was afraid to risk the experiment of boring down. Subsequent reflection has only confirmed him in the opinion that such a step would be hazardous, and the Committee have accordingly been most reluctantly compelled to renounce the plan. Mr. Bryham's final refusal was received on the 28th February.

Professor Ansted read a paper last year, in the Geological Section of the Association, upon the Alpine tunnel, commonly called the Mont-Cenis tunnel, and in that paper some interesting statements were made regarding its temperature. Since that time, Professor Ansted has interchanged very numerous letters with the Secretary, and has furnished much valuable information, gathered from Prof. Sismonda, of Turin, and from M. Borelli, the resident engineer of the tunnel. Observations which appear to be reliable have been made in bore-holes in the sides of the tunnel, and the temperatures thus observed have been compared with the estimated mean temperature at the surface overhead, which in the highest part is a mile above the tunnel, or 2905 metres above sea-level. It is directly under this highest part that the highest temperature is found in the walls of the tunnel, namely 29°·5 C., or 85°·1 F., which is 9° F. lower than the temperature found at the bottom of the Rosebridge shaft at the depth of only 815 yards. But though the tunnel is at more than double this depth from the crest of the mountain over it, we must bear in mind that the surface-temperatures are very different. In a paper published by the engineer of the tunnel, M. F. Giordano, the mean temperature of the air at the crest of the mountain (Mont Frejus) is calculated to be —2°·6 C., or 27°·3 F. Assuming this estimate to be correct, we have a difference of 57°·8 F. between the deepest part of the tunnel and the air at the surface vertically over it; assuming further, as we did in the case of Rosebridge in last year's Report, that the surface of the hill itself has a mean temperature 1° F. lower than that of the air above it, we have a difference of 56°·8 F., and the thickness of rock between is 1610 metres, or 5280 feet (exactly a mile). This gives, by simple division, a rate of increase of 1° F. for 93 feet; but a very large correction must be applied for the convexity of the ground; for it is evident that a point in the ground vertically under a steep crest is more exposed to the cooling influence of the air than a point at the same depth beneath an extensive level surface. No correction for convexity would be needed if the temperature of the air decreased upwards as fast as the temperature of the internal rock; but this is very far from being the case, the decrease being about $3\frac{1}{2}$ times more rapid in the rock than in the air. To form an approximate notion of the amount of this correction, we must determine, as well as we can, the forms of the successive isothermal surfaces in the interior of the mountain. The tendency is for all corners and bends to be eased off as we descend, so that each succeeding isothermal surface is flatter than the one above it. Accordingly, if we have a mountain rising out of a plain, without any change of material, the isothermals will be further apart in a vertical through the crest of the mountain than under the plain on either side; they will also be further apart

at the highest part of this vertical, that is close under the crest, than at a lower level in the same vertical. It would be absurd to pretend to fix the amount of the correction with accuracy; but it seems not unreasonable to estimate that, in the present case, the numer of isothermals cut through by a vertical line descending from the crest of the ridge to the tunnel itself is about seven-eighths of the number which would be cut through in sinking through an equal distance in level ground, other circumstances being the same. Instead of 1° in 93 feet, we should thus have 1° in $\frac{7}{8}$ of 93, that is, in 81 feet.

This is a slow rate of increase, and is about the same as Mr. Fairbairn found at Dukenfield. The rocks penetrated by the tunnel consist of highly metamorphosed material, and are described as belonging to the Jurassic series. No fossils have been found in them. For two-thirds of the length of the tunnel, beginning from the Italian end, they are remarkably uniform, and it is in this part that the observations have been taken. The following account of them has been given by Prof. Ansted (Pop. Sci. Review, Oct. 1870, p. 351):—"The rocks on which the observations have been made are absolutely the same, geologically and otherwise, from the entrance to the tunnel, on the Italian side, for a distance of nearly 10,000 yards. They are not faulted to any extent, though highly inclined, contorted, and subjected to slight slips and slides. They contain little water and no mineral veins. They consist, to a very large extent indeed, of silica, either as quartz or in the form of silicates, chiefly of alumina, and the small quantity of lime they contain is a crystalline carbonate."

This uniformity of material is very favourable to conduction, and the high inclination of the strata (in which respect these rocks resemble those at Dukenfield) also appears to promote either conduction proper or aqueous convection, which resembles conduction in its effects. As regards Mons. Giordano's estimate of the mean air-temperature at the crest, it is obtained in the following way:—The hill of San Theodule is 430 metres higher, and the city of Turin is 2650 metres lower than the crest; the temperature of the former has been determined by one year's observations to be $-5°·1$ C., and that of the latter is 12°·5 C. If a decrease of 1° C. for every 174 metres of elevation be assumed (1° F. for 317 feet), we obtain, either by comparison with San Theodule or with Turin, the same determination $-2°·6$ for the air-temperature at the crest of the ridge over the tunnel.

This mode of estimating the temperature appears very fair, though of course subject to much uncertainty; and there is another element of uncertainty in the difference which may exist between the air-temperature and the rock-temperature at the summit.

These two elements of uncertainty would be eliminated if a boring of from 50 to 100 feet were sunk at the summit, and observations of temperature taken in it. The uncertain correction for convexity would still remain to be applied. It would therefore be desirable also to sink a boring, of about the same depth, in the plateau which extends for about a quarter of the length of the tunnel, beginning near the Italian end, its height above the tunnel being about a third of a mile.

In November last, when very little information had reached this country respecting the temperature-observations in the tunnel, an urgent appeal was addressed, jointly by your Committee and by the Geographical Society (of which Prof. Ansted is Foreign Secretary), to M. Sismonda, requesting him to use his influence with the Italian authorities to secure a series of accurate observations of the temperature in the sides of the tunnel, before time had been allowed for this temperature to undergo sensible change from its original

value. It was also suggested that the mean temperature of the surface overhead should be examined by boring.

M. Sismonda speedily replied, stating that he fully recognized the importance of such experiments, and had already made arrangements with the Government at Turin, and with the contractors for the railway works, to have them carried out as fully and fairly as possible. Had the communication reached him at a time of year when he could have travelled without great inconvenience, he would have gone to the spot himself; but as that was now impossible, the Government Commissioner for the works, M. Salvatori, had undertaken to see the experiments carried through by employés under his orders. M. Sismonda further stated that, from the commencement of the tunnel, the Academy of Sciences of Turin had instituted a series of scientific observations in it, in which observations of temperature were included. The results of these observations he promised to forward as soon as they were completed and tabulated.

On the receipt of the final refusal to bore down at the bottom of Rosebridge Colliery, inquiries were instituted as to the feasibility of executing a similar operation in the deepest part of the Alpine tunnel. The contractors have, however, declined to grant permission, as the operation would involve additional encumbrance of the very narrow space in which their works are proceeding. It appears that a length of a mile or more in the deepest part of the tunnel has not yet been opened out to the full width, so that opportunity may yet be given to excavate a lateral heading and bore down, if the Association encourage the plan.

Mr. G. J. Symons has repeated his observations in the Kentish Town well, at every fiftieth foot of depth, from 350 to 1100 feet, which is the lowest point attainable. As the water begins at the depth of 210 feet, all these observations may be regarded as unaffected by the influence of the external air, and they have now been sufficiently numerous at each depth to render further verification needless. The following are the results finally adopted, and they do not differ materially from those first published (Report for 1869).

Depth, in feet.	Temperature.	Difference for 50 feet.	Difference from 69°·9.	Difference from 1100 ft.	Feet per degree.
ft.	°	ft.	°	ft.	
350	56·0				
400	57·9	1·9	13·9	750	54·0
450	59·0	1·1	12·0	700	58·3
500	60·0	1·0	10·9	650	59·6
550	60·9	·9	9·9	600	60·6
600	61·2	·3	9·0	550	61·1
650	61·3	·1	8·7	500	57·5
700	62·8	1·5	8·6	450	52·3
750	63·4	·6	7·1	400	56·3
800	64·2	·8	6·5	350	53·8
850	65·0	·8	5·7	300	52·6
900	65·8	·8	4·9	250	51·0
950	66·8	1·0	4·1	200	48·8
1000	67·8	1·0	3·1	150	48·4
1050	69·0	1·2	2·1	100	47·6
1100	69·9	·9	·9	50	55·6

The numbers in the last column are the quotients of those in the two preceding, and denote the average number of feet of descent for 1° F. of increase, as deduced from comparing the temperature at each depth of observation with the temperature at the lowest depth. The earlier numbers in this column of course carry more weight than the later ones. The amount of steadiness in the increase of temperature of the water is best seen by inspecting the third column, which shows that the freest interchange of heat occurs at about the depth of 600 feet. This must be due to springs. The soil, from the depth of 569 to that of 702 feet, is described as "light-grey chalk, with a few thin beds of chalk-marl subordinate." The soil consists in general of chalk and marl, from 325 to 910 feet, and below this of sandy marl, sand, and clay (see list of strata in last year's Report, p. 41). The mean rate of increase in the former is a degree in 56 feet, and in the latter a degree in 49 feet. The mean rate of increase from the surface of the ground to the lowest depth reached is certainly very nearly 1° F. in 54 feet.

Mr. David Burns, of H.M. Geological Survey, has furnished observations taken in the W. B. lead-mines, at and near Allenheads, Northumberland, by the kind permission of Thomas Sopwith, Esq., F.R.S., and with the valuable assistance of Mr. Ridley, Underground Surveyor, who continued the observations after Mr. Burns had left.

The mineral for which these mines are worked is galena. There are very extensive old workings at a lower level than the present workings, and filled with water, which is kept down by pumping; but the quantity daily pumped out is very small in comparison with the whole, so that the change of water is slow.

From the offices of the lead-mines a small windlass with a supply of fine brass wire was obtained, which enabled the thermometer to be lowered steadily and quickly.

The first observations were taken in Gin-Hill shaft, 3rd June, 1871. The observers proceeded as far down in the works as they were able, and took their station in a level leading from the shaft, 290 feet from the surface of the ground, and 38 feet above the surface of the water in the shaft.

The following observations were then made:—

Depth under ground. ft.	Depth in water. ft.	Temperature. Fahr. °
340	12	49·3
340	12	49·2
390	62	51·2
390	62	51·2
440	112	51·3
440	112	51·3

The mean temperature at the shaft mouth for the year ending 31st May 1871, was 44°·3, as derived from daily observations of maximum and minimum thermometers, without applying a correction for diurnal range. Adding 1° to this, to obtain the probable mean temperature of the surface of the ground, and taking the temperature at 400 feet of depth as 51°·3, Mr. Burns computes that the rate of increase downwards is 6° in 400 feet, or 1° in 66·6 feet. The data for this calculation are obviously in many respects very uncertain.

On the 21st June Mr. Ridley took observations in another shaft in the same workings, called the High Underground Engine Shaft. It is sunk

from a level at the depth of 398 feet below ground, and the surface of the water in it is 399 feet down the shaft, or 797 feet below the surface of the ground. There are pumps in the shaft, but they had been stationary for more than 24 hours before the observations were made. Immediately after the observations they were started, and when they had been working for some time the temperature of the water lifted was found to be 65°·2. They draw their water at a depth of 957 feet below the surface of the ground.

The following were the observations:—

Depth under ground. ft.	Depth in water. ft.	Temperature. Fahr. °
807	10	65·1
807	10	64·9
857	60	65·4
857	60	65·7
807	10	65·4

The thermometer could not be lowered beyond 857 feet without risk of losing it, by getting fast in the wooden framework with which the pumps were secured. Mr. Burns thinks that some of the temperatures here recorded are too low, from the index being shaken down by reason of the impediments presented by the upper portions of the framework. The surface of the ground over this shaft is about 300 feet higher than over Gin-Hill shaft. If we allow 1° for this increase of height, and call the temperature of the surface of the ground 44°·3, as against 45°·3 at Gin Hill, we have, by comparison with the observed temperature 65°·7 at the depth of 857 feet, an increase of 21°·4 in 857 feet, or 1° in 40 feet.

On the 6th July Mr. Ridley took observations in another sump or underground shaft at Slitt mine, Weardale. This shaft is sunk from the lowest level in the working, and had been standing full of water during the five months which had elapsed since it was sunk. The only source of disturbance was a little water running along the level across the top of the shaft, so as to enter the shaft (so to speak) on one side and leave it on the other. This may affect the temperature at 3 feet, but could scarcely affect the temperature at 53 feet, which may be regarded as very reliable.

The following are the observations :—

Depth under ground. ft.	Depth in water. ft.	Temperature. Fahr. °
610	3	64·5
610	3	64·5
660	53	65·1
660	53	64·9

Mr. Burns says "the surface-temperature at Slitt mine will be nearly the same as that at Gin-Hill shaft, judging from their relative elevations, aspects, and exposure to the winds." Assuming it then to be 45°·3, and reckoning the temperature at 660 feet as 65°, we have an increase downwards of 19°·7 in 660 feet, or 1° in 33·5 feet. The only datum that seems doubtful here is the surface-temperature. If, instead of 45°·3, it be assumed as $\left\{\begin{matrix}44°·3\\46°·3\end{matrix}\right\}$, it gives an increase of 1° in $\left\{\begin{matrix}31·9\\35·3\end{matrix}\right\}$ feet.

Mr. Ridley has also taken observations in Breckon-Hill shaft, which is near the river Allen, about 1½ mile from Gin-Hill shaft, and at an elevation

not much above the bottom of the valley, but 1174 feet above sea-level. It was sunk some years ago, and has since stood nearly full of water. At the time of the observations the surface of the water was 24 feet down the shaft. The following are the observations taken in this shaft on June 13th:—

Depth under ground. ft.	Depth in water. ft.	Temperature. Fahr. °
50	26	47·2
50	26	47·2
100	76	46·9
100	76	46·8
150	126	46·8
150	126	46·7
200	176	46·6
250	226	46·8
300	276	46·8
350	326	46·9

These observations were taken early in the morning, when the air and springs were so cold as to allow the maximum thermometer to be cooled below the temperature of the shaft. In order to test more thoroughly the apparent uniformity of temperature from 100 feet down to 350 feet, Mr. Ridley took a second series of observations, extending from the 22nd to the 27th June. In these observations the thermometer was lowered in a tin case filled with water colder than that of the shaft. The thermometer was supported within the case in a vertical position by a wooden frame, and prevented from shaking about. It was allowed to remain at each depth several hours, was then lifted, and read with all possible care. The following are the observations thus obtained:—

Depth under ground. ft.	Length of immersion. h m	Temperature before immersion. °	Temperature after immersion. °
42	10 40	42·0	46·5
92	11 20	44·0	46·5
142	11 40	42·4	46·6
192	12 20	46·1	46·6
242	34 0	44·0	46·6
292	13 40	45·4	46·6
342	10 25	45·4	46·6

Here the temperature is even more uniform than in the first series. As to the causes of this uniformity, Mr. Burns remarks that the shaft is not connected with any working, but is cut through solid strata. It is a few yards to the east of the Allen, while, in the bed of that stream, and making a great spread on the west side of the valley, is a bed of limestone nearly 70 feet thick, and dipping at an angle of about 10° to the east. The top of this limestone was cut in the shaft about 40 feet down, *which occasioned a great influx of water into the shaft, and drained a strong spring on the other side of the river.*

It will be observed that the chief difference between the two sets of observations is just at the place where this limestone was cut. The second set were taken after and during much rain, and the first set after a week of very little rain. It appears probable that the difference of temperature at this

depth was due to the difference of temperature of the surface-water which soaked in through the limestone in the two cases. As regards the temperatures at depths exceeding 200 feet, it would appear that, in times of comparative drought (as in the first set), the heat of the soil at the greater depths has time to produce a little augmentation in the temperature of the water before it soaks away.

This shaft is obviously not adapted for giving any information as to the rate of increase downwards. Collecting the best determinations from the other shafts we have:—

	Depth of thermometer.	Temperature. Fahr.	Calculated increase.
	ft.	°	° ft.
Gin-Hill Shaft..........	400	51·3	1 in 66·6
High Underground Engine	857	65·7	1 in 40
Slitt Mine	660	65·1	1 in 33·5

Mr. Burns considers that little or no weight should be attached to the first of these determinations, as a pumping-engine was working in a neighbouring shaft communicating with it at the time when the observations were taken. The jump of 2° in descending from 340 to 390 feet also renders the interpretation of these observations difficult.

The closeness of the temperatures in the other two shafts, at depths differing by about 200 feet, suggests the idea that they are both fed by the same spring, and that the temperatures indicated are the temperature of the origin of the spring slightly modified by the different temperatures of the strata through which it has passed; but their positions appear to render this impossible.

Mr. Burns's opinion from all the observations is that the mean rate of increase downwards at Allenheads is about 1° in 35 feet; but this cannot at present be held as proved.

The strata consist mainly of alternate beds of sandstone and shale, with a few beds of limestone intermixed. In Slitt mine there is also a bed of basalt 158 feet thick, overlying the vein of fluor-spar in which the workings are carried on, the workings being 55 feet down in this vein.

Preparations are being made for taking observations in the dry part of the mines, by making shallow bores at different levels, inserting the thermometer, plugging up the hole for a few days, and then reading.

Another gentleman connected with H.M. Geological Survey, Mr. R. L. Jack, has taken observations in a bore at Crawriggs, Kirkintilloch, near Glasgow. They were taken on the 29th November 1870, the temperature of the air being 34°. The surface of the water in the bore was 6 feet below the surface of the ground, the latter being 200 feet above sea-level. The following were the observations:—

Depth from surface of ground.	Time of lowering thermometer.	Time of withdrawing thermometer.	Temperature. Fahr.
feet.	h m	h m	°
50	12 52 P.M.	1 7 P.M.	47
100	1 10 „	1 28 „	$48\frac{1}{4}$
150	1 33 „	1 52 „	$49\frac{1}{4}$
200	1 58 „	2 14 „	50
250	2 22 „	2 43 „	50
300	3 15 „	3 34 „	$50\frac{1}{2}$
350	3 40 „	3 50 „	51

A few feet below 350 feet an obstruction in the bore prevented further

observations; but the bore continues for about 70 feet further. We have here a total increase of 4° in 300 feet, which is at the rate of 1° in 75 feet; but the intermediate steps are so irregular that not much weight can be attached to this determination.

The Secretary has corresponded with the Smithsonian Institution respecting the great bore at St. Louis, which was described in last year's Report, and also respecting the Hoosac Tunnel which passes under a mountain and will be $4\frac{3}{4}$ miles long, but the correspondence has not yet led to any definite result.

It was stated in last Report that application had been made to General Helmersen, of the Mining College, St. Petersburg, for information regarding the temperature of a very deep bore in course of sinking at Moscow, as well as regarding underground temperatures in Russia generally. A long delay occurred, owing to the General being absent from home for seven months, and not receiving the communication till his return; but shortly after his return he dispatched a very polite answer, from which the following passages are extracted:—“ We have an artesian well in St. Petersburg, bored in the Lower Silurian strata. At the depth of 656 English feet this well stops at the granite, a granite which perfectly resembles that of Finland. The lowest portion of these Silurian strata is merely a degraded granite, a grit combined with débris of felspar. About 353,000 hectolitres of water flow from the well per diem, and this water issues with a constant temperature of 9°·8 Reaumur. . . . . . . You are doubtless aware of the existence of a series of observations on the temperature of the soil at the bottom of a well which was sunk in the town of Yakoutsk in Eastern Siberia. This well has shown us that the soil of Siberia, at least in this part of its great extent, is frozen to a depth of 540 English feet. The mean temperature of Yakoutsk is $-8°·2$ R. At the depth of 100 feet the temperature of the soil was found to be $-5°·2$. From this depth to the bottom the temperature increased at the rate of 1° R. for every 117 feet; whence it would follow that the soil at Yakoutsk is frozen to the depth of about 700 feet.

“ It appears to me a very interesting circumstance that, according to accounts just received by the Academy of Sciences from Baron Maydel, traveller in the country of the Tchukchees [des Tschouktschi], there are found in those regions layers of *ice, quite pure,* alternating with sand and clay. The interesting letter of the Baron will shortly be printed in the publications of the Academy. It was in making excavations in search of mammoths that Maydel made this discovery.”

If we assume the temperature of the surface of the soil at St. Petersburg to be 39°·17 F., which, according to ‘Herschel's Meteorology,’ is the mean temperature of the air at the Magnetic and Meteorological Observatory, and if we take the temperature of the water as that of the bottom of the well, we have an increase downwards of 14°·88 F. in 656 feet, which is at the rate of 1° F. in 44·1 feet. If, on the other hand, we suppose the surface of the ground to be 4° F. warmer than the air (and the difference at Yakoutsk appears to be greater than this), we deduce an increase at the rate of 1° F. in 60 feet.

The rate of increase at Yakoutsk from the depth of 100 feet to the bottom of the frozen well at 540 feet is given above by General Helmersen as 1° R. in 117 feet. This is 1° F. in 52 feet.

An account of the Yakoutsk well is given in ‘Comptes Rendus,’ tome vi. 1838, p. 501, in an extract from a letter by Erman (fils), who visited Yakoutsk when the well had attained a depth of 50 feet. He gives the tem-

perature at this depth from his own observations, and the temperatures at 77, 119, and 382 feet from the subsequent observations of the merchant to whom the well belonged. His figures differ very materially from those given above; but it may fairly be presumed that General Helmersen's account is the more accurate.

Before the receipt of General Helmersen's letter, the following communication respecting the Moscow boring had been received by the Secretary from Mons. N. Lubimoff, Professor of Natural Philosophy in the University of Moscow.

"December $\frac{13}{25}$, 1870.

"DEAR SIR,—I beg your pardon for not having replied sooner to your letter. I am sorry to say that the information which I can now communicate is very deficient. The great bore of Moscow is not yet terminated, and the experiments on temperature which have been made hitherto are but of a preliminary kind. It was in the hope of renewing the measurements under more satisfactory conditions that I delayed my answer; but as certain circumstances did not permit me to resume the observations, which are therefore deferred to the spring of 1871, I must restrict myself to describing the old ones.

"These were made, on my commission, by M. Schiller, B.A., in April 1869. The bore was then about 994 feet deep, and, from 56 feet to the bottom, full of water. A mercury thermometer of a peculiar kind was constructed, on an idea of my own. It consisted of a capillary tube of thick glass, terminating below in a large reservoir; at the upper end a funnel-like piece was adjusted, into which the mercury flowed off as soon as the temperature rose above a certain value [sketch annexed]. The whole was placed within a closed case, which was plunged to a chosen depth into the bore, and reversed by means of a special arrangement. It was then brought again to the right position and drawn up to the surface, a portion of mercury having flowed away. Here the thermometer was plunged into a water-bath, the temperature of which was so regulated that the mercury attained the end of the capillary tube; this was then the temperature required.

"The measurements were made at the depths of 175, 350, 525, 700, 875, and 994 feet. From 350 feet to the bottom the temperature throughout the bore was found to be nearly constant, namely 10°·1 C., with deviations of $\pm 0°·1$. The temperatures of the upper parts of the bore were not quite precisely ascertained, the chief attention being given, in these first experiments, to the deeper parts. The air-temperature at the surface for the time $\left(\frac{17}{29}\text{ April to }\frac{23\text{ April}}{5\text{ May}}\right)$ varied between $+7°·5$ and $-1°·9$ C.

"As soon as the boring is completed, and the present impediments removed from the bore, the observations will be resumed, and perhaps some new methods will be applied for the sake of verification, though the above described apparatus, previously tried, seemed to give very exact results.

"I shall be very glad to communicate to you, as soon as possible, the results of the new experiments. As to underground temperatures for Russia in general, there is, so far as I know, no place where regular and trustworthy observations have been made [*should be made* in original] except the Central Physical Observatory at St. Petersburg, the results of which are published by Dr. Wild, Director of the establishment, in his printed Annual Reports."

From the sketch annexed to the description in Professor Lubimoff's letter, it appears that the enlargement at the open end of the capillary tube is quite sudden, and not likely to retain any mercury when inverted. The idea of error from this cause may therefore be dismissed; but the instrument is en-

tirely unprotected against the pressure of the water in which it is immersed, and it is important to consider what effect this pressure will have.

In thermometers of the ordinary construction this pressure acts only externally, and produces much greater diminution of the internal volume than when, as in Prof. Lubimoff's thermometer, it acts both externally and internally, a mode of action with which we are familiar in the case of Œrsted's piezometer.

From Regnault's experiments it appears that the apparent compression of mercury in glass, when the pressure is thus applied, is ·000001234 per atmosphere, whereas the apparent expansion of mercury in glass for heat is ·0000857 per degree Fahrenheit. The latter number is 69 times the former; it therefore appears that a pressure of 69 atmospheres would be required to falsify the indications of Prof. Lubimoff's thermometer to the extent of 1° F. The actual pressure at the bottom of the well is less than the half of this, and therefore should only produce an error of a few tenths of a degree. This, however, is on the assumption that the glass undergoes no change of figure, a condition which may easily fail of being fulfilled, owing to the want of perfect uniformity in the glass.

Mr. Donaldson has written from Calcutta to the effect that the thermometer which was sent to him has been entrusted to a competent observer, who has taken numerous observations with it, which will be sent shortly.

M. Erman's letter above referred to is immediately followed in the 'Comptes Rendus' by an account, by M. Walferdin, of some observations, which appear to be very reliable, taken in artesian wells in the basin in which Paris is situated. They were taken with maximum thermometers of the kind invented by Walferdin himself, in which the mercury overflows into a reservoir when the temperature exceeds a certain limit, the thermometers being hermetically sealed in glass tubes to protect them from pressure.

The observations which he first describes were taken in a well, newly sunk to the depth of 263 metres, at St. André, about 50 miles to the west of Paris, and which failed to yield a supply of water. The temperature was carefully observed at the depth of 253 metres by means of two thermometers, which were allowed to remain at that depth for ten hours. Their indications agreed to ·03 of a degree Centigrade, and gave a mean of 17°·95 C. For the sake of comparison, M. Walferdin observed the temperature at the bottom of a well 75 metres deep, situated at a distance of only 13 metres from the other well, and found it 12°·2 C., showing a difference of 5°·75 C. in 178 metres, which is at the rate of 1° C. in 30·95 metres, or 1° F. in 56·4 feet. He mentions that he also employed two Six's thermometers (deux thermométrographes) enclosed in copper tubes to protect them from pressure, but both of these gave erroneous indications. The copper case of one was imperfect, and allowed a little water to enter. This one read 1°·25 too high, owing probably to the effect of pressure; the other read 2°·15 too low, owing probably to the index being shaken down.

The temperature at the depth of 400 metres in the puits de Grenelle at Paris was observed on two different occasions. The indications were 23°·5 on the first and 23°·75 on the second occasion; and these M. Walferdin compares with the constant temperature 11°·7 in the caves of the Observatory at the depth of 28 metres. Taking the mean of the two observations, 23°·6, we have a difference of 11°·9 in 372 metres, which is at the rate of 1° C. in 31·2 metres, or 1° F. in 56·9 feet.

Observations in the well of the Military School, at a distance of 600 metres from the puits de Grenelle, showed a temperature of 16°·4 C. at the depth of

173 metres. This gives, by comparison with the Observatory caves, an increase at the rate of 1° C. in 30·85 metres, or 1° F. in 56·25 feet.

These three determinations are in wonderfully close agreement with each other. All three wells are sunk in the chalk of the Paris basin. In the case of the St. André well the thicknesses of the different strata were:—

	metres.
Plastic clay	13·52
White chalk	122·46
Marly chalk	29·24
Glauconie	13·64
Greensand	84·36
	263·22

The thermometer which the Committee have been employing for the last three years is a Phillips's maximum, having so fine a bore that the detached column of mercury which serves as the index is sustained in the vertical position by capillary action, and will bear a moderate amount of shaking without slipping down. Numerous instances, however, have occurred in which the index has slipped in consequence of jerks or concussions sustained by the thermometer in hauling it up from a depth. During the past six months the Secretary has been in correspondence with Messrs. Negretti and Zambra respecting a proposed modification of the maximum thermometer known by their name, which occurred to him more than a year ago, and was described by him privately to some meteorological friends at the last Meeting of the Association. It was then supposd to be new, but it now appears that Messrs. Negretti and Zambra have made something of the kind for the last fourteen or fifteen years. Several changes, however, were necessary before the thermometer was adapted to the uses of the Committee, and the first complete instruments were received in June last. They are enclosed, like the thermometers previously used, in hermetically sealed tubes, for protection against pressure, and they have the advantages (1) of being able to bear more severe jolts without derangement of their indications, and (2) of presenting to view a much broader column of mercury, so as to be more easily read in a dim light.

The instrument is to be used in a vertical position, with the bulb uppermost. Between the bulb and the stem there is a contraction, through which the mercury will not pass except under pressure. It is set by holding it with the bulb end lowest, and tapping this end on the palm of the hand, till the part between the contraction and the bulb is full of mercury. It can then be held with the bulb up, and the mercury in the stem will run down to the lower end, from which the graduations begin. In this position, the top of the column indicates the temperature of setting, which must be lower than the temperature intended to be observed.

The instrument is then to be lowered into the bore to any required depth, and allowed to remain there for about half an hour, to ensure its taking the temperature of the surrounding water. The expansion of the mercury in the bulb with heat will force a portion of the liquid through the contraction, and subsequent cooling in hauling up will not cause any of it to return. The portion which has thus escaped from the bulb into the stem will usually be found remaining close to the contraction, when the thermometer has been hauled up. The instrument must then be gently inclined, so as to make the bulb end slightly the lowest, when the mercury in the stem will all unite into one column, which will run down to its place on again raising the bulb. The head of the column will then indicate the required temperature.

Report on Observations of Luminous Meteors, 1870–71. *By a Committee consisting of* JAMES GLAISHER, *F.R.S., of the Royal Observatory, Greenwich,* ROBERT P. GREG, *F.R.S.,* ALEXANDER S. HERSCHEL, *F.R.A.S., and* CHARLES BROOKE, *F.R.S., Secretary to the Meteorological Society.*

THE object of the Committee being, as in the previous year, to present a condensed Report of the observations which they have received, and to indicate the progress of Meteoric Astronomy during the interval which has elapsed since their last Report, the reviews of recent publications relating to Meteoric Science which will be found in the sequel are preceded by a statement of the results obtained by the observers, who have during the past year contributed a valuable list of communications on the appearances of luminous meteors and regular observations of star-showers to the Committee. The real heights and velocities of thirteen shooting-stars obtained by the cooperation of Mr. Glaisher's staff of observers at the Royal Observatory, Greenwich, during the simultaneous watch for meteors on the nights of the 5th to 12th of August last, are sufficiently accordant with the real velocity of the Perseids (as already previously determined by similar means, in the year 1863) to afford a satisfactory conclusion that the results of direct observation are in very close agreement with those derived from the astronomical theory of the August meteor-stream. Shooting-stars were observed to be more than usually frequent on the nights of the 17th of August and 24th of September last, accompanying on the latter night a rather brilliant display of the Aurora. On the nights of the 18th–20th of October last the sky was so generally overcast as to conceal the view of any meteoric shower which may have taken place on that well-established meteoric date. But on the mornings of 13th–15th of November last a satisfactory series of observations of the November star-shower (so far as its return could be identified) recorded at the Royal Observatory, Greenwich, and at several other British stations, concurs with very similar descriptions of its appearance in the United States of America in showing the rapid decrease of intensity of this display since the period of greatest brightness, which it attained in the years 1866 and 1867. Notices of the extreme brightness with which it was visible in the following year (1868) are extracted from astronomical and meteorological journals kept in Switzerland and Scotland. A short view of the sky on the night of the 12th of December last was obtained at Birmingham, where the accurate divergence of the meteors observed by Mr. Wood from the radiant point in Gemini of the December meteors sufficed to verify the periodical return of that meteoric current. The state of the sky was not favourable for observations of meteors on the first two nights of January; but during two hours, when the sky was clear, on the night of the 20th of April last, the well-known group of April meteors was noted, on the periodical date, diverging in considerable numbers, and with the characteristic features of brightness, and leaving a persistent streak from the direction of a nearly fixed centre in the constellation Lyra. One meteor of the shower, simultaneously observed at Birmingham and Bury St. Edmunds, afforded sufficiently accurate materials for calculating its real distance from the observers, and the length and velocity of its visible flight relatively to the earth. The combined observations of the regularly recurring meteor-showers during the past year having at present proved successful in contributing some valuable materials to their history, the Committee propose to resume during the coming year a systematic watch for their return, and to provide observers

of the regular star-showers of August and November, and those of smaller interest and abundance in January, April, October, and December, with suitable maps and instructions to enable them to obtain, without unnecessary pains bestowed in preparations or expense, the most careful and complete records of their extraordinary displays. In order that the operations of the Committee may thus continue to be systematically directed towards the objects which have acquired important interest from the discovery of the astronomical connexion of shooting-stars with the orbits of comets, introducing the strictest methods of inquiry into the laws of their appearance, the Committee earnestly desire the renewal, in the coming year, of the support which, since its first formation, by their correspondence and cooperation, observers have hitherto freely contributed to the British Association.

Notices of the appearance of twenty-two fireballs and small bolides have during the past year been received by the Committee, fourteen of which were compared to the apparent size and brightness of the moon, and the latter include three detonating meteors of the largest class. Descriptions of some of the largest of these meteors are contained in the accompanying list and in the following paragraphs of the Report. No notice of the fall of an aërolite during the past year has been received, although the occurrences of large meteors during the months of autumn and spring, preceding April last, were more than ordinarily frequent. Of one of these, which appeared with unusual brilliancy in Cornwall, Devonshire, and the south-western counties of England on the evening of the 13th of February, it is possible to estimate, at least approximately, the locality and the real elevation of its flight. Careful observations of such phenomena when they appear are, however, again recommended by the Committee to all observers who may have the necessary astronomical skill, and the rare opportunity to note their brilliant courses by the stars.

In the discussion of some papers on Meteoric Astronomy which follow the foregoing observations, it will be seen that in the hands of its talented originator, Prof. Schiaparelli, the cosmical theory of periodical shooting-stars has received fresh and valuable illustrations, and the apparently inexplicable grouping of radiant-points for several successive days in the neighbourhood of a general centre of divergence, if not explained, appears to depend upon effects of planetary disturbances of a single meteoric stream from which the parasitic radiant-points have been derived. The discussion of such examples is simplified, and their complete explanation is, perhaps, not beyond the reach of the persevering application with which skilled astronomers in every country are now bent on the solution of the complicated and intricate geometrical problems presented to them by the distribution and features of the known radiant-points of shooting-stars. To a brief description of this interesting memoir are added, at the close of the Report, some notices of works which have recently appeared on the more general branches of meteoric science.

I. Meteors doubly observed.

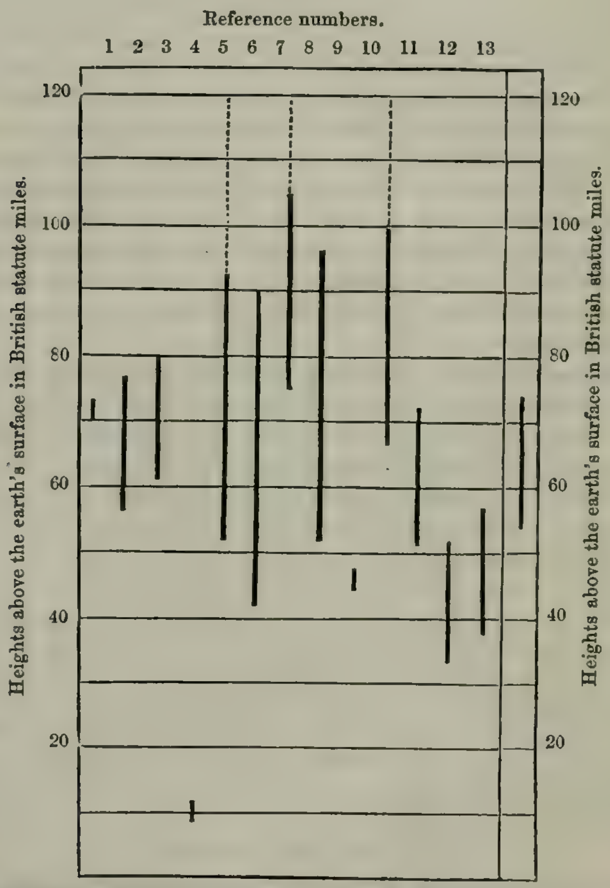
1. A Table of the real heights of sixteen shooting-stars doubly observed in England during the meteoric shower of August 1870, independently of the observations recorded at the Royal Observatory, Greenwich, was presented in the last volume of these Reports. A comparison of the observations made on that occasion at the Royal Observatory, Greenwich, with those recorded at the other stations, enables the real paths of thirteen meteors (ten of which are new to the former list), seen by Mr. Glaisher's staff of observers, to be satisfactorily determined; and the real heights and velocities of the

meteors thus identified, together with the particulars of the observations from which they are concluded, are entered in the Table opposite.

The accompanying diagram (drawn on the same scale as that in the last Report) readily exhibits to the eye the actual heights at appearance and disappearance (or the heights of the centres of the visible paths of the meteors Nos. 1, 4, 9) above the earth's surface. The last vertical line on the right represents (as in the last Report) the average height at first appearance and that at disappearance of all the meteors regarded as identified in the present list, of which the approximate heights of those points have been satisfactorily ascertained. The resulting average heights are:—

	At first appearance.		At disappearance.
Of 16 meteors in the last Report....	74·1	B. S. miles.	47·6
Of 10 meteors in the present list ..	71·7	„	54·4
Of 20 meteors observed in Aug. 1863	81·6	„	57·7

Fig. 1.



Heights at appearance and disappearance of thirteen shooting-stars simultaneously observed at the Royal Observatory, Greenwich, and at other stations in England, August 6th–11th, 1870. (Nos. 1, 4, 9 are calculated heights at the centres of the real paths.)

The present average heights are somewhat less than those observed in the year 1863; but they agree more closely with the general average height at first appearance, 70·05 miles, and that at disappearance, 54·22 miles (as given in the Report for 1863, footnote on p. 328), of nearly all the shooting-stars

[*To face page* 28.

—(B.) Birmingham; (H.) Hawkhurst, Kent; (L.) Regent's Park,
ust, 1870.

Reference Number.	Velocity in B. S. miles per second.	Position of the radiant-point.			Observers, Remarks, &c.
		R. A.	N. Decl.	Approximate by the stars.	
		°	°		
1.	......	......	......	....	G. L. Schultz. W. H. Wood.
2.	15	195	+64	κ Draconis.........	W. C. Nash. R. P. Greg.
3.	......	......	......	....	W. Barber. F. Howlett. Course apparently ascending?
4.	......	......	......	....	W. C. Nash. T. Crumplen. A very doubtful accordance.
5.	123?	26	+58	ε Cassiopeiæ	W. Marriott, W. Barber. A. S. Herschel.
6.	73?	50	+54	α Persei	W. C. Nash. A. S. Herschel.
7.	123?	23	+58	ε Cassiopeiæ	W. Marriott, W. Barber. T. Crumplen.
8.	92?	27	+62	ε Cassiopeiæ	T. Wright, W. Marriott, W. Barber. A. S. Herschel.
9	......	40	+71	Custos Messium...	T. Wright, W. Marriott. A. S. Herschel.
10	......	......	......	....	W. Barber. A. S. Herschel.
11	27	45	+62	B Camelopardi...	T. Wright, W. Marriott, W. Barber. A. S. Herschel.
12	39	40	+57	η Persei	T. Wright, W. Marriott, W. Barber. A. S. Herschel.
13	52	54	+67	B Camelopardi...	W. Barber. A. S. Herschel.
	37 miles per sec.	46	+62	β Camelopardi ...	Average velocity and position of the radiant-point of the Perseids, Nos. 11, 12, 13.

Real Heights and Velocities of Shooting-stars simultaneously observed at the Royal Observatory, Greenwich (Gr.), and at other stations in England—(B.) Birmingham; (H.) Hawkhurst, Kent; (L.) Regent's Park, London; (M.) Manchester; (T.) East Tisted, Hants—on the nights of the 6th–11th August, 1870.

Reference Number	Date, 1870, August.	Place of observation	(Approximate Hour;) G. M. T.	Apparent magnitude, as per fixed stars, &c.	Colour.	Streak, and its duration.	Observed points of: Appearance. R. A.	Appearance. N. Decl.	Disappearance. R. A.	Disappearance. N. Decl.	Recorded length of path.	Recorded duration.	Computed heights and places of: Appearance. B. S. Miles	N. lat.	Long.	Disappearance. B. S. Miles	N. lat.	Long.	Length of path in B. S. miles.	Velocity in B. S. miles per second.	Position of the radiant-point. R. A.	N. Decl.	Approximate by the stars	Observers, Remarks, &c.
			h m s									sec.												
1	6	Gr.	11 11 2[illegible]	2	Bluish	None	[illegible]	+7	centre	of	path		(71	52 50	0 25 E	centre	of	path.)	...				...	G. L. Schultz
		B.	11 11 15	2	Yellow	......	23	+4	16	+32	...	5												W. H. Wood
2	8	Gr.	10 10 6	1	Bluish white.	Streak.	175	+56	170	+53	......	......	77	53 22	1 49 W	56	53 8	1 32 W.	29	15	195	+64	κ Draconis	W. C. Nash.
		M.	[illegible]	Venus	Bluish white.	Streak.	3[illegible]8	+45	318	+24	......	2												R. P. Greg.
3	10	Gr.	10 25 25	3	White.	......	27	+55	2	+38	......	......	61	51 39	2 3 E	80	51 56	1 19 E	42	......	......	......	......	W. Barber. Course apparently [illegible]
		T.	[illegible] 25	2	..		29	+41	6	+24	...	...												T. Howlett
4	10	Gr.	10 29 2	>1	White.	......	160	+65	170	+56	......	0·7	(10	51 43	0 14 W.	centre	of	path?)	......	......	......	......	......	W. C. Nash. A very doubtful
		L.	(10 28 30)	1½	......	Bright streak.	145	+80	185	+66	......	......												T. Crumplen. accordance.
5	10	Gr.	10 33 10	1	Bluish white.	Streak.	10	+60	315	+54	15	1	14[illegible]?	52 1[illegible]	2 3[illegible] E	52	51 37	[illegible] 2 E	135?	123?	26	+58	ε Cassiopeiæ	W. Marriott, W. Barber
		H.	[illegible] 32	2	White	½ second.	22	+67	24[illegible]	+[illegible]	25	1·2												A. S. Herschel
6	10	Gr.	[illegible] 47 4[illegible]	Jupiter.	Yellowish.	Fine streak	6[illegible]	+67	14	+8	1[illegible]	1·2	9[illegible]	53 4	1 15 E	41	52 4	0 7 W	100?	73?	50	+54	α Persei	W. C. Nash
		H.	[illegible] 4[illegible]	>Capella	Orange red	½ second	88	+69	155	+62	25	1·5												A. S. Herschel.
7	10	Gr.	[illegible] 55 1[illegible]	2	Bluish white	Bright streak	18	+59	8	+6	[illegible]	[illegible]	135	52 3	2 3 E	75	51 54	0 57 E.	86?	123?	23	+58	ε Cassiopeiæ	W. Marriott, W. Barber
		L.	10 50 0	3	......	......	20	+58	2	+52	......	......												T. Crumplen.
8	10	Gr.	11 1 4	2	......	Streak.	7	+56	344	+32	1	[illegible]	95	52 2	1 25 E	52	51 34	0 43 E	6[illegible]	92?	27	+62	ε Cassiopeiæ	T. Wright, W. Marriott, W. Barber
		H.	11	3	White	1 second.	27	+72	27	+8[illegible]	8	6												A. S. Herschel
9	11	Gr.	10 37 50	2	Bluish white.	......	18	+59	1	+32	......	0·5	(44	51 33	1 0 E.	centre	of	path?)	......	......	40	+71	Custos Messium	T. Wright, W. Marriott
		H.	[illegible] 3[illegible]	2	Yellow	None	332	+58	31[illegible]	+[illegible]	6	[illegible]6												A. S. Herschel
10	11	Gr.	[illegible] 39 2		Yellowish.	Fine streak.	24[illegible]	+66	257	+4	2[illegible]	1·5	200?	......	......	60	51 27	0 57 W.	......	......	......	......	......	W. Barber
		H.	(10 37 0)	2	White.	2 seconds.	235	+58	232	+38	25	0·9												A. S. Herschel.
11	11	Gr.	11 4 18	1	Bluish	Fine streak	34[illegible]	+45	333	+3		1·5	72	51 2[illegible]	0 5[illegible] E.	51	51 12	0 28 E	31	27	45	+62	B Camelopardi	T. Wright, W. Marriott, W. Barber
		H.	11 2	α Lyræ	[illegible]	Bright, 3 seconds	3[illegible]	+71	3[illegible]5	+[illegible]4		[illegible]												A. S. Herschel
12	11	Gr.	11 [illegible]8 26	1	Yellowish	Fine streak	1[illegible]	+65	325	+63	[illegible]	[illegible]	51	51 52	[illegible] 23 E	33	51 3[illegible]	[illegible]5 E	25	39	4[illegible]	+57	η Persei	T. Wright, W. Marriott, W. Barber
		H.	11 3[illegible] 3	3	White	None	1[illegible]5	+81	1[illegible]3	+[illegible]	12	0												A. S. Herschel
13	11	Gr.	11 45	2	Bluish	Streak.	350	+45	344	+28	12	..	56	51 26	[illegible] 41 E	38	51 14	0 25 E.	26	52	54	+67	B Camelopardi	W. Barber
		H.	11 43 3	3	..	None	32[illegible]	+78	287	+6[illegible]		5												A. S. Herschel
Average heights and length of path, omitting doubtful values marked thus (?), in British statute miles													7[illegible]			54·4	One centre of path, 71 miles.)		3[illegible]·4	37 miles per sec	46	+62	β Camelopardi	Average velocity and position of the radiant-point of the Perseids, Nos. 11, 12, 13.

simultaneously observed until the beginning of that year. The average velocity of the Perseïds, relatively to the earth, observed in the year 1863 was 34·4 miles per second, and that of the three Perseïds satisfactorily well observed in the present list is 37 miles per second. In his original letters to Father Secchi on their connexion with Tuttle's comet (Comet III., 1862), now universally accepted as a true basis of their cosmical theory, Prof. Schiaparelli calculated, from the known elements of the comet's orbit, that the velocity with which the Perseïds enter the earth's atmosphere (allowing for a very minute influence of the earth's attraction) is 38 miles per second. That the direct determination of the velocities of the August shooting-stars which were made last year should, in this instance, so exactly agree with the value found by calculation (although from the small number of identifiable meteors the probable error of the determination is rather large), is, from the great scale and general excellence of the observations, at least provisionally, a successful confirmation of the astronomical theory of the August meteors, and a satisfactory conclusion from the simultaneous watch.

2. During the corresponding observations of the meteor-shower of November last, in which the observers of Mr. Glaisher's staff at the Royal Observatory, Greenwich, also took an important share, the coincidence of the times of appearance and of the other particulars of a single meteor only of the shower simultaneously observed at Greenwich and at Tooting, near London, could be established, the descriptions of which, as given by the observers at those stations, were as follows:—

No. in Lists.	Date.	Approximate hour. G. M. T.	Place of observation.	Magnitude as per stars.	Colour.	Duration.	Apparent course.	Appearance, streak, &c.
7	1870 Nov. 15	h m s 1 5 56 A.M.	Royal Observatory, Greenwich.	= 1st magnitude star.	Bluish white.	0·7 seconds.	From θ Ursæ Majoris, passed a little below Polaris, in the direction of β Cephei.	Left a streak.
(8)	„ 15	1 5 0 A.M.	Tooting, London, S.W.	= Sirius.	White.	Short duration.	From between the 'Pointers' of the Great Bear, shot one-third of the way towards α Cygni.	Left a long streak lasting a second or two.
7	„ 15	1 5 56	Greenwich...	Length of path 15°. Observer, Wm. Marriott.				
(8)	„ 15	1 5 0	Tooting	Meteor fairly well observed. Observer, H. W. Jackson.				

The apparent paths of the meteor among the constellations present a considerable parallax in the right direction of displacement, as seen from the two observers' stations, to lead to a positive determination of its real altitude above the earth. The concluded path of the meteor is nearly horizontal at a height of about fifteen miles above the earth's surface. The small distance (only seven miles) between the two stations, greatly increasing the effect of the errors most difficult to avoid in the observation and description of such transitory phenomena, must, however, for the present be regarded as precluding certainty from the conclusion, which would otherwise attach to this unusually low elevation of a meteor's real path.

3. Preparations for observing the meteors of the 20th of April last were also made at many stations in England and Scotland with only partial success. A meteor of the April shower was, however, observed simultaneously at Birmingham and Bury St. Edmunds, of which the following descriptions were recorded:—

No.	Date.	Approximate hour. G. M. T.	Place of observation.	Magnitude as per stars.	Colour.	Duration.	Apparent course.	Appearance, streak, &c.
(6)	1871. Apr. 20	h m 11 8 P.M.	Birmingham	=1st magnitude star.	Blue.	1·25 second.	From A_4 Herculis to γ Draconis—8°.	The meteor increased in size.
(9)	„ 20	h m s 11 10 15 P.M.	Thurston, near Bury St. Edmunds.	=1st magnitude star.	White.	3 seconds.	From $\frac{1}{5}$ α Draconis, ζ Ursæ Majoris, crossing τ Ursæ Majoris, to $\frac{1}{4}$ (k 12) Lyncis.	Small in the first, growing brighter in the last half of its course. Left a slender streak at first, which remained 2 seconds on the last half of its course.
(6)	„ 20	11 8	Birmingham	Length of path 11°. One-third of the sky overcast. Observer, W. H. Wood.				
(9)	„ 20	11 10 15...	Thurston ...	Length of path 45°. Sky very clear. Observer, A. S. Herschel.				

Although the times at both the stations were uncertain to rather more than a minute from true Greenwich time, and the approximate times of the meteor's appearance recorded at the two stations differ from each other by rather more than two minutes, yet the very similar descriptions of its appearance at the two stations, and the fact that no other meteor at either station preceded it or followed it within a quarter of an hour, during a very attentive watch, as well as the good agreement together of the apparent paths recorded by the two observers, render it scarcely possible to doubt that the same meteor was simultaneously observed. The apparent length of path and duration are, however, much longer at Bury St. Edmunds than at Birmingham, where the meteor was seen foreshortened near the radiant-point; and on this peculiar circumstance Mr. Wood (in a letter to Mr. Herschel) makes some important remarks, which offer a very interesting field for further observations. "My view of the meteor's course was evidently very oblique, and yours, very direct (nearly at right angles), would obscure a faint tail to me. There is also another peculiarity which I have observed in oblique-visioned courses, that they appear to endure about half the time of that obtained by direct vision, which I fancy arises from its invisibility to one observer, whilst it is visible to the other in the earliest portion of its flight, and the amount of the invisible course to bear some proportion to the recorded differences in the durations." In perfect agreement with this explanation the point of disappearance of the meteor is well fixed (by combining the observations) at a height of about sixty-five miles above a place near Bourne, in Lincolnshire. The observations, on the other hand, do not agree in determining the point of first appearance. The first and faint half of the meteor's apparent path, as recorded at Bury St. Edmunds, is placed too far from the north pole of the heavens to be nearly comformable to the radiant-point near δ Lyræ (from some point near and below which the apparent course of the meteor, as seen

at Birmingham, was directed), while this portion of the meteor's flight appears to have entirely escaped observation at Birmingham. Prolonging the meteor's visible flight at Birmingham 7° backwards towards the radiant-point, and approaching the point of first appearance at Bury St. Edmunds about the same distance towards the north pole of the heavens, the agreement of the observations in fixing the point of first commencement at a height of about eighty miles over the neighbourhood of Norwich is nearly as exact as the determination of the place of the meteor's disappearance. The length of its visible path was about seventy-five miles, and its radiant-point in Taurus Poniatovii, on the same meridian, was about 40° south of the usual radiant-point (QH_2) of the April meteors. Although its apparent course, as observed at Bury St. Edmunds, evidently denoted it as an erratic member of the group, its general resemblance to the other Lyraïds observed on the same evening was a remarkable feature in its long and striking course. Adopting Mr. Wood's suggestion of (provisionally) increasing the duration, as observed at Birmingham, from 1·25 to 2 seconds in the simple proportion of the increased length of the apparent course, prolonged towards the radiant-point, and adopting $2\frac{1}{2}$ seconds (the average between this duration and that recorded at Bury St. Edmunds) as the time of flight, the resulting velocity, relative to the earth, of this single member of the April meteoric stream doubly observed on the night of the 20th of April last, was, within very few miles, about thirty miles per second. The theoretical velocity of the same meteors (see the Note on the last page of this Report) is not quite thirty miles per second.

4. Several observations of the very brilliant fireball observed in Devonshire and in the south-western counties of England on the evening of the 13th of February last were collected and compared together by Mr. Wood, the result of whose investigation will shortly be given, with descriptions of that meteor, as the most probable conjecture, from the materials at present at their disposal, arrived at by the Committee respecting its real height and the locality of its nearest approach to the British isles.

II. Large Meteors.

In addition to the conspicuous meteors described in the accompanying list, the following descriptions of remarkable meteors have appeared, or were communicated to the Committee by the observers:—

1. 1870, Nov. 1, $11^h\ 30^m$ P.M., London. "I saw a splendid meteor last night, at $11^h\ 30^m$, *through the blind of my bedroom window.* The whole room was illuminated, and the meteor must have been at least half as large as the moon. I went to the window quickly, but could see no trail. The path must have been, say, 5° to the right of α Aurigæ, *ending* 10° to left of α, β Geminorum. I only saw the end.

"T. Crumplen, London, N.W., Nov. 2nd, 1870."

2. 1870, Nov. 4, shortly before 3^h A.M. (local time), Agra, India:—

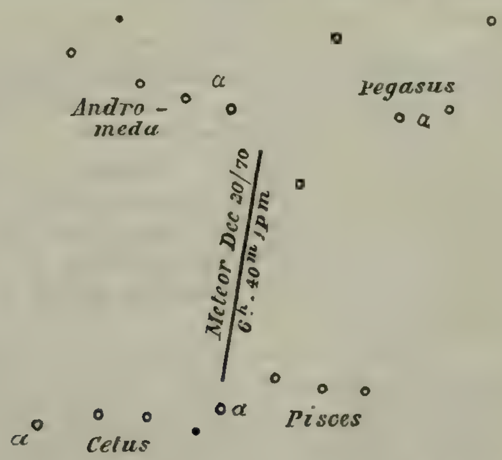
Extraordinary Meteor.—"The following account of an extraordinary meteor occurs in a letter I received from a brother who is a missionary stationed in Agra. He does not give the exact place where he was at the time, but it must have been very near to Agra. The letter is dated Agra, 24th November, 1870. A missionary from Allahabad was with him when he saw it.

"Mills Hill, Chadderston, near Manchester. Robert Gryson.

"Agra, Nov. 24, 1870.—I recently saw a marvellous meteor. I was in camp, and had risen for an early march a few minutes before 3 A.M. on

November 4th. I was standing under the shade of a cluster of trees, when a sudden flash of light fell around. Two or three camp fires were blazing near, and at first I thought it might be a sudden flare up from one of them; but on casting my eyes up towards the heavens, I saw a large oval light, stationary. It appeared to be composed of a large number of irregularly shaped, differently sized stars, yet so closely packed as to form one light, yet giving the whole a sort of dappled appearance. At first I was struck dumb with amazement—thought it must be some mental illusion, or that my eyes were playing me false. But as I gazed it remained steadily fixed. ———, of Allahabad, was with me. I roused him; he was soundly asleep, and some seconds passed in waking him up. In the interval it appeared to have been lengthened, nearly, though not quite, by a straight line, and as we gazed it assumed the shape of a large magnet, with the upper limb rather shorter than the other. It then gradually expanded, diminishing in brightness as it increased in size, assuming a wavy, serpentine form, though keeping much to a horseshoe shape, until it became so attenuated as to be no longer visible. It must have continued in sight five minutes. It was seen by all the servants; and one of them cried out, 'Bhagwauka seela hae,' by which he appeared to mean that in his opinion the Almighty was amusing Himself with fireworks; literally, 'It is God's sport or amusement.'"—*Nature*, Jan. 12th, 1871.

3. 1870, Dec. 20, 6^h 40^m P.M., Hawkhurst, Kent.—"This evening at 6^h 40^m I noticed the descent of a beautiful meteor. It appeared to start almost from the zenith towards the S.S.E., and it was visible for about three seconds. It had very much the appearance of a sky-rocket in its flight, but without any explosion, and it displayed vivid red and orange colours. The evening was very dark, but the stars were visible; the meteor did not increase the amount of light in the place where I was walking. According to my 'star-map,' I should lay down its course as follows." [See the sketch of the meteor's course.]—T. HUMPHREY, Hawkhurst, Dec. 20th, 1870.



4. 1871, Feb. 13, 9^h 4^m P.M., Bristol.—"I saw a very brilliant meteor last evening, February 13th, at 9^h 4^m. During the time that it continued visible the whole of the sky was illuminated by the light it emitted. The first appearance of the meteor was not witnessed, but the direction and situation of the latter portion of its path was approximately determined. It passed through the S. part of Orion, just under Rigel, so [see sketch]:—

It disappeared near B, which is equal to about R.A. 4^h 10^m, Decl. S. 15°. At A it left a train about 2° in length, which endured for ten minutes. In that portion of the sky near which the meteor disappeared many stratus clouds were visible.

"P.S.—I omitted to state that the brilliancy of the meteor excelled that of any of the planets. When at its brightest the light was about equal to that of a clear full moon. I only saw the disappearance."—WILLIAM F. DENNING, Bristol, February 14th, 1871.

At Rugby the meteor was observed very bright at about 9^h 10^m P.M., and it was described as "starting from near θ Orionis, and proceeding towards a point a little north of γ Eridani, when it was lost behind a belt of cloud." (Communicated to 'Nature,' February 16th, 1871, by J. M. WILSON.)

These two descriptions of its visible path (apparently from the relative positions of the stations) are so similar that little can be certainly concluded from them regarding the real distance of the meteor.

At Exeter "a brilliant meteor traversed the constellation of Orion, appearing near the Belt and passing from south to west. The direction was south-west, altitude 35°. Its light equalled or exceeded that of full moon, and it left a train of colours for some time." ('English Mechanic,' Feb. 24th.)

At Torquay, "The meteor started near Bellatrix in Orion, altitude 35°, passing due west, leaving in its track a brilliant train of colours, green predominating." (*Ibid.*, March 3rd.)

The meteor was also seen at Callington, in Cornwall, casting a brilliant diffused light, and occupying two seconds in its transit. (*Ibid.*)

By comparing together the foregoing observations of its course, and obtaining an approximate estimation of its real height, Mr. Wood is led to adopt the following provisional positions of its visible track. The meteor first appeared at an elevation of fifty-five miles over the English Channel, seventy miles S.S.W. from Torquay. It thence descended, with an inclination of 16°, to a height of thirty-five miles over a point sixty-four miles west of Torquay, thus describing, from S.E. by S. to N.W. by N., a path of eighty miles in two seconds, across the centre of the county of Cornwall, terminating at its western coast, near St. Columb Minor. The radiant of the meteor was near α Hydræ. As the meteor was probably distinctly seen in Cornwall, the Scilly Isles, and in the south of Ireland, additional descriptions of its apparent course from those places, as seen from points considerably west of the place where it appears to have approached the earth, would afford the best materials for verifying the present approximate conjecture of its real path. As seen at Torquay, it was notably described by an observer to Mr. Greg as lighting up the whole bay and presenting a magnificent appearance.

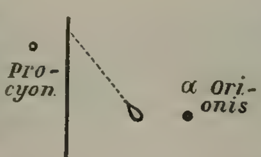
5. 1871, July 31st, 9^h 27^m P.M., Bristol.—" I observed a meteor of some brilliancy on Monday evening last, July 31st, at 9^h 27^m. It was first seen a little above β Pegasi, and passing downwards obliquely, it went about 3° east of α Pegasi, and disappeared when it reached a point somewhere near R.A. 13°, N. Declin. 29°. It left no train of light that was perceptible, and I suppose that the meteor was visible for about three seconds. As far as could be

Observations of

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Apparent Course.
1870. Sep. 12	h m 10 25 p.m.	Camden Town, London.	3 × ♃, large disk...	Blue............	Slow moving...	Began near α Ursæ Majoris, and ended near Cor Caroli.
„ 23	8 10 p.m.	Birmingham ...	One-third diameter of the full moon, or 2 × ♀.	Pale blue......	About 2 secs...	Commenced at α=66, δ=+39
Oct. 2	10 8 p.m.	Ibid	> ♃	Silvery-white..	3 seconds......	α= δ= From 92° +44° to 116 +37
„ 29	12 15 a.m.	Glasgow	= ♃.................	Red	0·4 second ...	Commenced at Cor Caroli.
Nov. 13	9 37 59	Royal Observatory, Greenwich.	> ♃	Yellowish......	3 seconds......	Passed midway between α and κ Draconis, and continued its path parallel to ζ and η Ursæ Majoris.
„ 21	9 35 p.m.	Glasgow	= ♃..................	White	3 seconds......	From ½ (β, δ) Aurigæ to o Ursæ Majoris.
„ 20	9 0 p.m.	Scarborough ...	Apparent shape and size of the half-moon.	Bluish	....	Descended from a point about 15' above the S.W. horizon.
1871. Mar. 1	10 10 p.m.	Charing Cross, London.	> ♃	Brilliant white	About 3 secs...	From near β Canis Minoris to about 5° or 6° east of and at the same altitude as, α Orionis.
„ 17	About 10 40 p.m. (local time).	Paris, Rochelle, &c., France.	Splendid meteor ...	Green	20 seconds ...	....

judged it was of a red colour, and somewhat star-like in appearance. At the time of its appearance the sky was rather cloudy and misty, and the meteor was not, therefore, seen advantageously. It did not seem to explode at the time of its extinction. I have sent the above particulars thinking they may be useful for comparison with other results."—William F. Denning, Cotham Park, Bristol, August 2nd, 1871.

ırge Meteors, 1870–71.

Appearance; Train or Sparks.	Length of Path and Direction.	Remarks.	Observer and References &c.
very large globular nucleus. Seen through haze, which dimmed its light.	25°; downwards to left...	The stars scarcely visible through haze, but recognized sufficiently near the meteor's path.	T. Crumplen.
globular nucleus, without tail or streak.	>10°; directed from Capella, radiant F_1.	View of the end of its course intercepted when at an altitude of 4° or 5°.	W. H. Wood.
ucleus pear-shaped, with short adhering white tail, projecting dull-red fragments forwards on its course; increasing and exploding at maximum brightness.	From radiant F_1	....	Id.
....	5° while in sight; directed from θ Ursæ Majoris.	From radiant α Tauri. End of path hidden by houses.	Robert Maclure.
ːft a very fine streak ...	40°	....	T. Wright.
ft no streak	15°; from radiant in Taurus	....	Robert Maclure.
ıe meteor only seen as it passed behind the edge of a cloud.	Fell perpendicularly ↓	Appeared with two flashes, which lit up all the heavens.	T. H. Waller.
ıcleus pear-shaped, followed by a short train for a second. Point of first appearance near houses, which concealed the neighbouring star Procyon.		Sky clear. The meteor appeared extremely bright in the full moonlight.	F. H. Ward.
explosion; but many sparks projected from the nucleus. Left a luminous track, which remained visible for more than an hour.	....	Seen also at Chichester, $10^h\ 30^m$ p.m., > ♀, from near the zenith, with a remarkably long duration, to near the S.W. horizon. Bright gold colour at last, leaving a brilliant train visible for 3 or 4 minutes ('The Times,' Mar. 21st).	Messrs. Prevost, Samberg, and other observers ('Comptes Rendus,' March 20th, 1871).

Date.	Hour.	Place of Observation.	Apparent Size.	Colour.	Duration.	Apparent Course.
1871. Mar. 18	h m 12 20 a.m. (local time).	Turin and other places in Piedmont.	Apparent diameter of full moon.	Brilliant white	About 2 minutes. Very protracted course, and slow speed.	Passed directly over the town of Turin from the mountains near Susa, towards the opposite horizon.
" 23	6 35 p.m.	Broadstairs (Kent).	Disk of apparent size of Sirius, including his rays.	Nucleus green, with red train.	....	First appearance at a point about 30° above the N. ½ E. horizon.
" 24	4 25 a.m. (local time).	Volpeglino, and other stations in Piedmont.	Nucleus 25′ diameter.	Brilliant white	Slow and stately motion.	From α Cygni, across α Andromedæ, to near ζ Piscium, or $\alpha=$ $\delta=$ From 309° +45° to 10 + 7
Apr. 11	9 46 p.m. (local time).	Ibid, Moncalieri, Piedmont.	Nucleus 10′ diameter.	Bluish white...	....	$\alpha=$ $\delta=$ From 211° −10° to 223 +28 [From 221 −11 to 111 +28 From 175 +15 to 111 +32]
" 12	8 15 p.m. (local time).	Lodi; Moncalieri, Piedmont.	Very large and brilliant.	Reddish, then bright blue.	....	From 111 + 7 to 105 + 2
" 14	11 39 p.m. (local time).	The Observatory, Naples.	= ♃	White	....	From 98 +70 to 15 +39
" 22	10 37 30 p.m. (local time).	Moncalieri, Piedmont.	= ♃	....	....	From 233 +23 to 18 +88 (Polaris). [From 212 +20 to 87 +45]

6. Meteors of the largest class, as described in the foregoing list of such occurrences, were more than ordinarily frequent during the months of March and April last, appearing principally on the nights of the 17th–18th and 23rd–24th of March, and on those of the 11th and 12th of April last. On the first of these dates two fireballs were observed in France and Italy, the former of which was also seen in the south of England, at Chichester. A large meteor was seen in Kent and Essex, on the second date, a few minutes after sunset; and two detonating meteors were observed at Urbino, and were generally visible in Italy on the same night. The third detonating meteor of which accounts have reached the Committee, made its appearance in Piedmont on the evening of the 12th of April last. Professor Serpieri and Mr. Denza, at the Observatories of Urbino and Moncalieri, near Turin, are collecting sufficient details of these large meteors to calculate their real course.

Appearance; Train or Sparks.	Length of Path and Direction.	Remarks.	Observer and References &c.
Nucleus an elongated mass of stars. Left an immensely broad and bright streak, which remained visible for 10^m or 15^m.	Horizontal, from W.N.W. to E.S.E.	....	Letter in Turin newspaper (by F. Denza) of Mar. 31st.
Nucleus followed by a train of red sparks. Exploded, projecting many luminous fragments.	15°; descending towards the east, at an inclination of about 45°.	The meteor was also seen at Leyton, Essex, a few minutes after sunset, appearing in the E.N.E., and taking a southerly direction. (J. F. Duthie, 'Nature,' Mar. 30th, 1871.)	Communicated by Jas. Chapman.
Left a few bright red sparks and a very persistent ruddy streak on its whole course.	....	Burst with a violent detonation; heard about ½ a minute after its disappearance. [Seen and heard at Urbino, where it was preceded at 2^h a.m. by a perfectly similar detonating meteor equally brilliant, and leaving a persistent streak.—A. Serpieri.]	Letter in Turin newspaper of March 31st, 1871, by F. Denza.
Nucleus very brilliant. At π Boötis it paused for an instant, and advanced with irregular motion towards its termination. Left a brilliant streak.	....	[The last two apparent positions are those at Alessandria, and Volpeglino, where the meteor was also observed.]	Communicated by F. Denza.
....	....	Burst with a detonation, which was heard in houses with closed doors.	Id.
Left a reddish streak for 20 seconds.	....	....	Id.
Nucleus followed by a bright streak, which remained visible for 3½ minutes.	....	[The last apparent position is that observed at Volpeglino (Tortona), where the meteor was also seen, and its bright streak remained visible for one minute.]	Id.

III. Aërolites.

The following dates of aërolitic falls appear to have escaped notice in the Catalogue (Report for 1860) and in subsequent Reports:—

Date.	
1804, November 24	San Luis Potosi, Mexico.
1864, June 26	Volynia, Russia.
1865, February or March ..	Gorruckpore, India.
1866, October 5	Ahmednuggur, Bombay.
1867, January 19..........	Khetrie, Rajpootana, India.
1868, May 22	Slavetic Croatia.
1868, November	Danville, Alabama, U.S.
1868, December	Frankfort, Alabama, U.S.
Date unknown	Goalpara, Assam.

The analysis of the last of these meteorites by Mr. Tschermak (Jahrbuch für Mineralogie, for 1871, p. 412) shows approximately the following composition:—

Iron.	Hydrocarbon.	Olivine.	Enstatite.	Magnetic Pyrites.	
8·49	+0·85	+61·72	+30·01	+(traces)	=101·07.

The occurrence of carbonaceous matter in the meteorites of Hessle, Upsala (1st January, 1869), was recently also recognized by Nordenskjöld, who found in them a black flocculent substance, containing 71 per cent. of carbon. (The 'Academy,' August 15th, 1871.)

IV. Meteoric Showers.

1. *Meteor-showers in January and February* 1837.—From the tracks of meteors recorded in the last annual Catalogue of the British Association, and in the 'Bulletin of the Moncalieri Observatory' for November 1869, observed during the months of January and February of that year, Mr. Greg has established the existence of the following old, and of one new radiant-point, which made their appearance in those months:—

Duration of meteoric shower in 1869.	Position of radiant-point.			Number of meteors mapped.	Symbols, durations, and positions of the same meteor-showers in the British Association Report for 1868, p. 401.				
					Symbol.	Duration.	Position.		
	α.	δ.	By the stars.				α.	δ.	By the stars.
Jan. 9–19, and Jan. 30 to Feb. 6	72°	+ 2°	*s*, *z*, Orionis...	14 (Italian)..	(AG_1	Dec. 20 to Feb. 6.	68	+20	α Tauri)?
Jan. 29 to Feb. 6	223	+54	In Quadrans...	7 (Italian)...	K_3	Jan. 2–3	232	+49	*c* Quadrantis.
Feb. 11–20 (chiefly) ...	194	+15	ε Virginis	8 (English)..	S_4	March 5–17	190	+ 1	γ Virginis.
Feb. 11–16 (chiefly) ...	103	−25	δ Canis Majoris.	10 (English and Italian).	Γ_2	January	105	−27	δ Canis Majoris.
					Γ_3	February	105	−45	Puppis, Argo.

A succession of radiant-points near the apex of the earth's way following the appearance of the November shower, of which the general meteor-shower LH (Report for 1868, p. 403) from the head of Hydra, lasting until the 12th of December, presents a parallel instance, is remarkably described in the following MS. note, recorded by the late Sir J. Herschel during his residence at the Cape:—"Cape of Good Hope, 1837, January 2nd, 1^h 30^m M. T. [*i. e.* from midnight]. A meteor=second-magnitude star crossed the zenith, leaving a train. Course right *from the apex in the east*, whence they have all come since November 12th. N.B. This has been extremely remarkable and well-sustained; really very few exceptions.

"February 1–5.—The meteors now chiefly go from S.W. to N.E."

The tendency of radiant-points to group themselves in families so as to make newly observed centres difficult to distinguish from older ones appearing nearly on the same date, is well seen by the examples of the new radiant-point in Orion, and of the extensions (apparently) of old radiant-points, pointed out by Mr. Greg. Some attempts to explain this singular peculiarity and the striking instances of groups of radiant-points in the months of January and February have recently been published by Professor Schiaparelli, a further account of whose speculations on their probable history will be found at the close of this Report.

2. *The Meteor-shower of November* 1868, which was seen in its greatest brilliancy in the United States of America, and which was also partially recorded at Glasgow, by Professor Grant, between 5 and 6 o'clock on the morning of the 14th of November, was observed at the same hours in the north of Scotland, and described in the 'Journal of the Scottish Meteorological Society' (for December 1868):—"*Meteors and Falling-stars.*—The star-shower of the 13th and 14th of November was observed at many of the stations. In the north it was very fine. Mr. Clark, the observer at North Unst, writes:—'On the morning of the 14th there was a great falling of shooting-stars from all directions of the sky; it was something like a shower of stars.' And the Rev. Dr. Hamilton observes that at Bressay 'There was an extraordinary meteoric shower, which continued from 3^h 30^m A.M. of the 13th [? 14th] till the sun rose, and the number of stars or meteors falling was innumerable.'" The following descriptions of its appearance in Switzerland are given by Dr. Rudolf Wolf in his 'Astronomical Contributions':—"1868, November 13th: from 12^h 5^m to 12^h 15^m I saw four, from 12^h 15^m to 12^h 30^m nine, and from 12^h 30^m to 12^h 40^m two brilliant meteors radiating from the constellation Leo. The sky (up to the latter time quite clear) then clouded over from the east, and all further view of the meteors at Zürich was prevented. Mr. Rieder, at Klosters, reports:—'As an unusual phenomenon I have to state that at 4^h 15^m on the morning of the 14th of November, 1868, an extraordinary number of shooting-stars were visible in the western sky; from five until six o'clock a real rain of shooting-stars took place, diffusing such great brightness that one might easily have read by their light. Several of the meteors left streaks of bright light in the sky, which remained visible for two or three seconds.' At Engelberg 'from five until after six o'clock A.M. on the morning of the 14th of November, repeated flashes of lightning were perceived, and shortly before five o'clock a swiftly passing flash, like a ball of light, was observed, whilst the sky was completely overcast.'" An admirably compiled history of the November phenomenon in the year 1868, comprising the exact details of observations at all the places where it was well observed, and notices of its general description at places in all parts of Europe, the United States of America, and the Atlantic, where it was witnessed, is published in his Memoirs V. and VI., on 'Shooting-stars of November 1868 and August 1869,' by Sig. F. Denza. The same volume contains (in the sixth memoir) an equally full collection of observations and theoretical deductions of great value regarding the appearance of the August meteor-shower in the year 1869. Among the latter may be cited the suggestion of Professor Newton*, borne out by the observations of the shower made in America, and by those of Professor Serpieri at Urbino in that year†, that the radiant-region of the Perseids is in reality a narrow, elongated space extending from near the cluster at χ Persei to the star B (B. A. C. 1058) Camelopardi. The radiant-region of the Leonids in the previous year was similarly observed by Professor Newton to be better represented by a short line extending between the stars ϵ, γ Leonis, from about the star x, in the centre of the Sickle (B. A. C. 3423), to the latter star, than by a single point. The direction of elongation of the radiant-region is towards the sun's apparent place, a conclusion which is regarded by Prof. Newton as throwing light of some importance upon the theory of the November meteor-stream.

* Bulletins of the Royal Academy of Sciences of Belgium, ser. 2. vol. xxvi. 1868, pp. 450, 451.

† Letter from Prof. Serpieri to Prof. Schiaparelli, January 5th, 1870; communicated to the Royal Institute of Sciences of Lombardy.

3. *The August Shower in* 1870.—In the 'Meteorological Bulletin' of the Moncalieri Observatory for October 1870, the first results of observations in Piedmont on the star-shower of the 10th and 11th of August last are communicated. As already observed in the last Report, the frequency of the meteors did not exceed the ordinary average of the shower, and they were somewhat more frequent on the night of the 10th than on that of the 11th of August. They appeared to proceed from several radiant-points, besides the principal one of the shower, in Perseus. Among the contemporaneous radiant-points, T_2, F_1 (the former occurring in August in Pegasus, and the latter usually appearing in Auriga in the latter part of September) were observed to be conspicuous.

4. *The November Shower in* 1870.—The preparations made for recording the return of the November meteors in 1870 were in a great measure disappointed by the cloudy state of the sky at several of the English stations.

The following letter from Mr. Backhouse announced a more favourable condition of the sky at Sunderland on the morning of the 14th of November than that which prevailed at Manchester, Birmingham, York, and London, where no meteors of the shower could be observed:—

"Between $2^h\ 20^m$ and $3^h\ 42^m$ A.M., on the 14th, I watched for meteors; I only saw seven in fifty-six minutes, watching in a cloudless sky. Of these only four belonged to the shower. I enclose the particulars. I did not watch much on the morning of the 15th. It was mostly cloudy, and I saw no meteors."—Of the conformable meteors two left trains, one was stationary close to, and the others radiating very nearly from, the small star x Leonis. The unconformable meteors appeared with short courses in and near the constellation Taurus, and of these one was as bright as Sirius. It was of a yellow colour, describing a path of 3°, near ϵ Arietis, from the direction of the Pleiades, and it left no streak.

Five meteors, from undetermined radiant-points, were seen through breaks in the clouds by Mr. J. E. Clark, at York, on the morning of the 14th, and two Leonids of some brightness, in a watch of one hour (interrupted by the clouds), on the morning of the 15th of November.

On the morning of the 14th of November the sky was clear at Glasgow from $2^h\ 10^m$ until $5^h\ 15^m$ A.M., and twenty-six meteors were recorded by Mr. A. S. Herschel, of which twenty-one were conformable. Of the latter the paths of eleven, prolonged backwards, crossed, and of five passed close to the curve of Leo's sickle. Seven meteors left persistent streaks, which were faintly visible in the full moonlight. The proportion of magnitudes of the conformable meteors was:—

Of meteors equal to or brighter than a	1st-mag. *;	2nd do.;	3rd do.;	4th do.
Number of meteors seen	3	6	7	5

Meteors of smaller magnitudes were rendered invisible by the moon's light; and the most striking conformable meteor of the shower, recorded at $4^h\ 25^m$ A.M., was as bright as Sirius. It described a course of 25°, directed nearly from μ Leonis, in three-quarters of a second, and left a broad streak on its whole path for two seconds. The following numbers of conformable and unconformable meteors were recorded in the half-hours ending at

	h m	h m	h m	h m	h m	h m
1870, November 14th, A.M.	2 40	3 10	3 40	4 10	4 40	5 10
Conformable meteors	1	4	6	2	5	3
Unconformable meteors	1	0	0	4	0	0

In the first and last half-hours the sky was partially concealed by clouds; at $3^h\ 38^m$ A.M. a group of three first-, second-, and third-magnitude meteors,

leaving streaks directed from Leo, appeared almost together. In the next half-hour two meteors, directed apparently from Cor Caroli, appeared to be unconformable to the Leo radiant. The remaining unconformable meteors all proceeded from the direction of a radiant-point in Taurus. At $5^h\ 15^m$ A.M. the sky became completely overcast; but a shooting-star from the direction of Leo, of first magnitude, was observed by Mr. R. Maclure, at $6^h\ 20^m$ A.M., through an opening of the clouds. On the morning of the 15th the sky at Glasgow was again completely overcast.

On the evening of the 13th a bright meteor (described in the above List) was seen at the Royal Observatory, Greenwich, and three vivid flashes of light, between $12^h\ 15^m$ and $12^h\ 30^m$ A.M., on the 14th, which must have proceeded from large meteors, at an altitude of about 20°, due S. were seen through the clouds, which from this time overspread the sky during the remainder of the night. On the morning of the 15th a clear sky enabled Mr. Glaisher's staff of observers to make continuous observations of the meteors visible in the bright moonlight, from midnight until $5^h\ 33^m$ A.M., when the sky was again quite obscured by clouds. Fifty-three meteors were recorded, in this interval by the five observers, the apparent paths of forty-five of which were traced upon a map. Of the meteors so recorded, twenty-eight proceeded from the usual radiant-point in Leo, eight from a radiant-point situated apparently not far from Cor Caroli, seven from a radiant-point between Taurus and Musca, and two meteors from uncertain radiant-points.

The following were the numbers of the meteors observed in the successive half-hours ending at

	h m	h	h m	h	h m	h	h m	h	h m	h	h m	
1870, November 15th, A.M....	12 30	1	1 30	2	2 30	3	3 30	4	4 30	5	5 30	Total
Number of meteors seen......	2	2	3	2	2	1	7	6	8	7	13	53

A very beautiful meteor of bluish-white colour, and of the apparent size and brightness of Jupiter, proceeding apparently from the direction of the radiant-point in Musca, descended towards the east, at $4^h\ 45^m\ 25^s$ A.M., through an arc of more than 25°, in about three seconds, leaving a streak of light upon its course. Most of the conformable meteors left a persistent train, but none of those observed rivalled this fine meteor in brightness or in length of course. The proportion of apparent magnitudes of the remaining meteors, seen during the watch is shown in the following list:—

	Brighter than first-magnitude stars;	=1st do.;	=2nd do.;	=3rd do.	Total
Number of meteors seen......	6	24	17	5	52

From these descriptions of the meteor-shower it appears that, on both the mornings of the 14th and 15th of November, the number of the conformable meteors considerably exceeded that of the unconformable meteors which appeared during the hours of the continued watch; but that the scale of the shower, as it was observed in England, was very far inferior to the brightness with which it was recorded in the preceding year.

At Tooting, near London, Mr. H. W. Jackson observed on the mornings of the 14th, 15th, and 16th of November, and noted one shooting-star on the night of the 13th, but failed, on account of haze and clouds, followed by rain during the morning of the 14th, in securing another observation. Between midnight and $1^h\ 55^m$ A.M., on the morning of the 15th, eight meteors were carefully observed and mapped, and four or five smaller meteors were seen, all but two of which (of short course, near the radiant-point in Taurus) were conformable to the Leo radiant-point. Of these, the brightest, at $1^h\ 5^m$ A.M., which left a long streak, was simultaneously observed at Greenwich. Of the two unconformable meteors, that which appeared at $12^h\ 7^m$ A.M. was white

and nearly as bright as Jupiter, moving for two seconds in a slightly curved course from ν to ψ Orionis, and leaving a short streak upon its track. Flashes of faint reddish lightning were perceived at $12^h\ 28^m$ and $12^h\ 53^m$ A.M. Between $12^h\ 30^m$ and $1^h\ 30^m$ A.M. on the morning of the 16th some meteors were observed, but did not appear to present features worthy of special note.

At Newhaven, in the United States, three observers noted, in three hours, thirty-one meteors, of which only six were conformable to the radiant-point in Leo. On the following morning (the 14th) Professor Newton, with five other observers, obtained the following enumeration of the meteors visible in the half-hours ending at 1870, November 14th, A.M. :—

	h m	h	h m	h	h m	h	h m	h	h m	h m	
(1870, November 13th, P.M....	11 30	12)	12 30	1	1 30	2	2 30	3	3 30	3 45*	Totals
Conformable meteors	0	1	5	10	12	9	15	8	12	7	79
Unconformable meteors	6	8	4	7	8	10	15	7	7	2	74

After $3^h\ 45^m$ the sky was so nearly overcast that regular counting was abandoned, while in open spaces of the sky it was still apparent that up to six o'clock no marked increase in the number of the meteors had taken place. After half-past five, however, the clouds already began more nearly to cover the sky. (American Journal of Science and Arts, vol. i., January 1871.)

5. *Meteor-shower of December 12th*, 1870.—The state of the sky was not generally favourable for observations, Mr. H. W. Jackson reporting from Louth that on the nights of the 12th and 13th the sky was overcast, with frequent rain from $8^h\ 30^m$ P.M. on the night of the 12th. At Glasgow, York, and Manchester it was equally obscured. At Birmingham Mr. W. H. Wood was more fortunate in securing a short view of the sky on one of the periodic nights, and the following is his description of the shower:—

"The overcast state of the skies from the 10th to the 13th permitted only of a partial view of the character of the shower, which occurred during a temporary clearance of the sky for one hour only, from $11^h\ 30^m$ P.M. on the 12th to $12^h\ 30^m$ A.M. on the 13th. Five meteors were recorded in three-quarters of an hour, radiating accurately from radiant G (θ Geminorum). Meteors white or blue, and trainless (one observer)." A list of the recorded paths, and a description of the meteors seen, accompanies Mr. Wood's report. The position of the radiant-point from which the meteors approximately diverged was near the stars κ and δ, in Gemini.

No observations were recorded, owing to a cloudy state of the sky, on the shower-meteor nights of the 1st and 2nd of January, 1871.

6. *Meteor-shower of April 20th*, 1871.—The last well-marked appearance of the April meteor-shower, to the annual occurrence of which attention was first drawn by Herrick, in the United States, took place on the morning of the 21st of April, 1863†, when, for a few hours, meteors were observed by Mr. Wood, at Weston-super-Mare, to be as frequent as in a moderately bright August star-shower. Two Julian intervals of four years each having elapsed since that occurrence, the astronomical conditions of its reappearance suggested special preparations and a simultaneous watch, which were accordingly made for its return. Besides the staff of observers at the Royal Observatory, Greenwich, Mr. Glaisher's son, Mr. James Glaisher, volunteered to take part in the observations at Cambridge, where Professor Adams also offered his aid, to join in recording the shooting-stars which might be visible at the Observatory. The other observers who awaited the display were those who have most frequently assisted the Committee by their recorded observations at Glasgow, York, Manchester, Birmingham, and London. Such, how-

* In a quarter of an hour. † Report for 1863, p. 325.

ever, was the unfavourable state of the sky which prevailed during the forty-eight hours intended to have been devoted to the watch (and which continued to prevent further observations during the last remaining nights of the months of April), that with the exception of a few meteors of the shower observed by Mr. Wood at Birmingham, and of the corresponding group of meteors recorded by Mr. Herschel at Bury St. Edmunds, no unbroken series of observations were received. The sky first became quite clear at the latter place at $9^h\ 30^m$ P.M., and the following numbers of meteors were seen in the half-hours ending at—

	h m	h	h m	h	h m	h	h m	
1871, April 20.........P.M.	9 30	10	10 30	11	11 30	12	(12 30 A.M. April 21).	Total.
Number of meteors seen ...		3	1	3	1	11	6	25

All but eight of their apparent paths, projected upon a map, when prolonged backwards, pass across a circular area about 15° in width, of which the centre is at a point in R. A. 267°, N. Decl. 35°. Nine of these conformable meteors left bright trains. Of the eight unconformable meteors, four are widely erratic meteors of the same shower, and the remaining four moving in the opposite direction were directed from an unknown radiant-point in the south. The path of one of the latter was remarkably serpentine in the latter portion of the meteor's course. The following are the numbers of meteors of the different magnitudes observed:—

As bright as Jupiter or Sirius.	As 1st mag. star.	2nd.	3rd.	4th.	5th.	Total.
3	4	5	5	4	4	25

The last meteor was observed at $12^h\ 35^m$ A.M. on the 21st. The sky then rapidly clouding over did not permit the progress of the shower, at Bury St. Edmunds, to further watched. On the previous and on the following night the sky was also cloudy.

At Birmingham Mr. W. H. Wood recorded the appearance of nine shooting-stars between the hours of $10^h\ 20^m$ and $11^h\ 30^m$ P.M. on the night of the 20th of April, five of which were noted in the first, and four in the latter half of the watch; five meteors diverged from the constellation Lyra, three from that of Corona, and the remaining meteor moved transversely to the former ones from the neighbourhood of Polaris. The numbers of meteors seen of different magnitudes were, 1=Sirius, 2=1st mag.*, 1=3rd do., 5=4th do.: total 9 meteors. The brightest meteor of the shower moved with a nucleus of brilliant blue, flickering light, about the brightness of Sirius, from the direction of Corona. Soon after half-past 11 o'clock the sky became overcast, and remained so at 1^h and 2^h A.M. on the morning of the 21st, when regular watching was abandoned. The maximum, as far as could be ascertained from these observations, occurred after midnight on the morning of the 21st; the rate of apparition for one observer, while the sky was clear, being seven or eight per hour between ten and eleven o'clock, and twelve or fifteen per hour during the half-hour immediately before and that immediately after midnight. Between $11^h\ 15^m$ and $11^h\ 45^m$ P.M. on the night of the 21st, Mr. Wood observed no meteors at Birmingham, although one-third of the sky was visible, quite clear, through the broken clouds. The appearance of the April shower in this year appears, therefore, to have taken place on the date and at about the hour expected for its return, from the time of its last conspicuous appearance.

7. *Meteor-shower of July* 1871.—At sea, between Norway and England, Mr. A. S. Herschel watched for the periodical meteors (first pointed out by Capocci, at Naples) on the night of the 16th of July. The sky was perfectly clear from 11^h P.M. until 2^h A.M. on the morning of the 17th of July, and

seventeen meteors were observed, six in the first, six in the second, and five in the third hour of the watch. On the night of the 17th the sky was again clear; but three meteors only were observed in three-quarters of an hour, between $10^h\ 55^m$ and $11^h\ 40^m$ P.M. The meteors observed on both nights were small, and appeared generally with short courses near a radiant-region around π Herculis, from which they appeared to diverge. The number of meteors seen of the different magnitudes were, 2=1st mag.∗, 4=2nd, 4=3rd, 6=4th, 4=5th: total 20 meteors seen in $3\frac{3}{4}$ hours by one observer, in a clear sky, with no moon.

V. Papers relating to Meteoric Astronomy.

1. Under the title 'Alcuni Resultati Preliminari tratti dalle osservazioni di Stelle Cadenti publicate nelle Effemeride degli anni 1868, 1869, 1870;' Professor Schiaparelli communicates, in connexion with the three Catalogues of Shooting-Stars observed in Italy, published in the Ephemeris of the Milan Observatory for the years 1868, 1869, and 1870, a first report on the radiant-points obtained by mapping the meteor-tracks contained in them from January to June. For a convenient nomenclature of the radiant-points, the year is divided into seventy-two pentads, of five days each, of which six are contained in every month. While the first five pentads in every month are complete, the sixth, and last, consists of three, four, five, or six days, according to the length of the month to which it belongs. Since, however, the observations for a single night of the year only (collected from all the years) are combined together to detect the radiant-points, of which several may occur in each pentad, the letters of the alphabet added to the Roman number of a pentad (thus, XIX. *a*) designate the radiant-points in those pentads in the order in which they were successively discovered by Professor Schiaparelli. Besides a strict separation of meteors observed on one from those observed on the next following or on the next preceding night, to avoid the risk of confusing together meteors belonging to different radiant-points under a false assemblage of two radiant-points into a single meteoric-shower, Professor Schiaparelli distinguishes as different meteor-currents those whose radiant-points, as shown by laying down the recorded paths, are more than 10° apart. The precision with which the radiant-points must be determined (from the shooting-star observations *of a single night*) is necessarily very great, in order that this rule may be rigorously applied. Even omitting the errors of observation (which are frequently considerable), it is found that different meteoric showers present different characters of radiation. In some the radiant-region is small, and the meteor-tracks prolonged backwards meet nearly in a point, when it is called "exact"; in others it is larger, the meteor-tracks prolonged backwards crossing each other in a confused manner over a considerable apparent space, in which case it is called "diffuse." The shooting-stars which make their appearance within the radiant-region (when this is rather large) may appear to be moving in every variety of opposite directions, and their paths are usually noticed to be extremely foreshortened by perspective in this position. Lastly, if they diverge from two or more points the character of the radiation is said to be double or multiple; and it appears probable, on certain theoretical grounds, which will be shortly stated, that a diffuse radiant-region in general arises from the close assemblage of many radiant-points together into a multiple group. The November meteor-shower is an example of exact, and the August star-shower an instance either of multiple or of diffuse radiation, according to the various descriptions of the observers who have examined the direction of its radiant-point most

attentively. Meteoric showers composed principally of very small shooting-stars are confined to the parts of the heavens immediately surrounding the radiant-point; while those consisting of large meteors spread far from the centre of divergence, the meteors (apparently from their brightness) being as plainly visible when they are seen by transverse as when they are seen fore-shortened by very oblique vision. Meteor-showers of the former kind are called "contracted"; and of the latter kind "extended" (*stretta*; *larga*). The foregoing are the principal terms employed by Professor Schiaparelli in describing the meteor-showers of which the positions of the radiant-points have now been published. The explanation of the phenomena of "diffuse" and "multiple" radiant-points is ingeniously supplied by Professor Schiaparelli in the following manner. A very small nebular mass of meteoroids or of cometoids having been deflected from its original parabolic (or very excentric) into an orbit of moderate period round the sun by the attraction of some powerful planet in its path, the foremost and swiftest particles of the stream produced by this disturbance gradually gaining, and the slowest losing ground on the central particles of the mass, an elongated form of the mass is gradually assumed directed along the line of the meteoric orbit. The difference of velocity, or of periodic time, between the foremost and hindmost particles of the row is sufficient to ensure the gradual lengthening of the line, until the foremost particle joins with the last in forming a continuous ring or wreath of meteoric substance closing the orbit of the original meteoric cloud. Should the two ends, before meeting each other (as must usually be the case), have undergone different perturbations from the action of the planets, instead of exactly overtaking the retreating end, the foremost end of the wreath will overlap it, and the meteor-stream will begin to assume the form of a spiral curve of a single coil. When the foremost end has gained two revolutions upon the retreating one, a spiral of two coils will be produced; and continuing this process during many revolutions gained by one end of the coil upon the other, the wreath of meteoroids, without losing its continuity, will at last form an endless hoop, or belt, of many strands overlying and interlacing with each other in as many convolutions as the fastest particles have gained revolutions in their course upon the slower ones. The direction and velocity of the particles in one of the strands will also differ as widely as their positions from those of particles in a neighbouring strand, and the whole wreath, without ever losing its perfect continuity from end to end, will cross and recross itself in constantly going and returning waves. In these stages of transformation a meteoric stream would successively exhibit the characters of double and multiple radiant-points. Supposing the same process to continue, and new perturbations of the stream to be constantly deflecting particles from the front or rear into different courses, these particles overtaking each other at the point where the earth passes through the stream would produce the mixed assemblage of radiant-points and of directions of the meteors of the August shower, which give it the character of multiple or of diffuse radiation. In the following list of radiant-points those marked with an asterisk (*) were described in the last Report (1870, p. 98); those at the end of the list are not included by Prof. Schiaparelli in his present list, which only represents the most important radiant-points observed, at present, in the first half of the year. In the cases where their identity with radiant-points in Heis's list, or in that of the British Association†, is suggested by Professor Schiaparelli, the position and duration of those radiant-points are added for comparison in the same columns of the Table.

† Report for 1868, p. 401 *et seq.*

List of the Principal Meteoric showers occurring in the first half of the year whose radiant points are derived from observations of shooting-stars in Italy, published in the Ephemerid of the Milan Observatory, for the years 1868, 1869, and 1870. By G. V. Schiaparelli.

Sign or Symbol.	Date and duration of shower.	Apparent Position. α.	δ.	Character of radiation.	Characters of the Meteors, General Remarks, &c.	Authority.
II *a*.	Jan. 6	199°	+58°	Contracted and exact.	Observed in 1868 and 1869	Schiaparelli
II *b*.	Jan. 6	175	+48	....	" " "	"
III *a**.	Jan. 11–12	{184 182	+28 +29	....	Jan. 11, 1869 Jan. 12, 1869 }	"
[MG₁.	Jan. 1–25...	{172 187	+31 +40}	....	Maximum Jan. 24......................	R. P. Greg.
III *b*.	Jan. 12 ...	197	+59	Contracted and exact.	Jan. 12, 1869 (traces on Jan. 11, 1869), possibly a continuation of II *a*.	Schiaparelli
IV *a**.	Jan. 18 ...	232	+36	Most certain and exact.	A splendidly well-defined meteor-shower. Jan. 18 (traces on Jan. 19), 1869.	"
IV *b*.	Jan. 19 ...	198	+28	....	Jan. 19 (traces on the 18th), 1869.	"
IV *c*.	Jan. 19 ...	220	+40	....	Many small meteors Jan. 19 (*no trace* on the 18th), 1869.	"
IV *d*.	Jan. 19 ...	200	+58	Contracted and exact.	Jan. 19 (no traces on 18th), 1869; apparently independent of II *a*, III *b*, and V *b* from absence of intermediate meteors.	"
V *a*.	Jan. 21 ...	205	+49	....	Jan. 21 (no trace on 19th and 20th), 1869. Independent of the radiants IV *d*, VI *a*.	"
V *b*.	Jan. 24 ...	200	+56	Uncertain to 5°; diffuse, perhaps multiple.	Jan. 24, 1868, many meteors. ?Connected with VI *a*, VI *b*: see the following Table (p. 48).	"
VI *a*.	Jan. 25–27	205	+47	Uncertain to 5° ...	Chiefly Jan. 27, 1868. (Perhaps identical with the last?)	"
VI *b*.	Jan. 29 ...	198	+54	Extended; diffuse, perhaps multiple.	Jan. 29, 1868. No traces of this shower on Jan. 28.	"
VI *c**.	Jan. 28 ...	236	+25	Extended; confused, but distinct.	Jan. 28, 1868. ? If connected with VI *d* Jan. 30; no intermediate meteors.	"
VI *g**.	Jan. 28 ...	67	+25	Diffuse...............	Jan. 28, 1868. [Probably identical with the next.]	"
[AG₁.	Dec. 20–Feb. 6.	68	+20	Elongated and diffuse.	Maximum Dec. 24......................	R. P. Greg.
VI *d*.	Jan. 30 ...	225	+34	Extended, uncertain to 10°.	Jan. 30, 1868. ?Connected with VI *c*, VI *e*; but no intermediate meteors with IV *a*.	"
VI *e*.	Jan. 31 ...	221	+28	Contracted; well-defined.	Jan. 31, 1868. ?Connected in one group with IV *a*, IV *c*, VI *c* and VI *d*: see following Table (p. 48).	"
VI *f**.	Jan. 31 ...	134	+40	Few meteors	Jan. 31, 1868. Traces on preceding evenings.	"
[M₁, ₂.	Jan. 2–Feb. 9.	128	+40	....	Maximum Jan. 25–31	R. P. Greg.
VII *a*.	Feb. 3	153	+21	Contracted and exact.	Feb. 3, 1869; a few traces on preceding nights.	Schiaparelli
X *a**.	Feb. 16 ...	74 (71	+48 +41)	Apparently double and exact.	Feb. 16, 1868. Traces on the 15th. A few meteors only from the second radiant-point. Identical with the next.	"
[A₃, ₄.	Feb. 9–17 .	73	+40	Well-defined and limited.	....	R. P. Greg.

gn or mbol.	Date and duration of shower.	Apparent Position. α.	Apparent Position. δ.	Character of radiation.	Characters of the Meteors, General Remarks, &c.	Authority.
[A$_4$.	Feb. 15–28	76°	+40°	....	....	Heis.]
VI a*.	Mar. 20 ...	144	+48	Centre of an elongated radiant-region.	Mar. 20, 1868. From $\alpha=130°$ $\delta=+46°$ to $\alpha=162°$ $\delta=+60°$; evidently identical with the next.	Schiaparelli.
M$_6$.	Mar. 16–31	150	+47	....	....	Heis.]
IX a.	Mar. 31–Apr. 2.	260	+46	....	Mar. 31, 1868 } Endures three days. Perhaps connected as a twin-radiant with the next.	Schiaparelli.
		262	+49	....	April 2, 1868 and 1869... }	
IX b*.	Apr. 2–3 ...	258	+36	....	Apr. 2, 1868 and 1869 } Distinct from but may belong to the same family as Greg's QH$_1$ with centre near π Herculis.	,,
		260	+40	....	Apr. 3, 1868 }	
X a.	Apr. 9	255	+36	....	Apr. 9, 1869 }	
X b.	Apr. 9	246	+46	....	Apr. 9, 1869. Twin-radiant with the last.	,,
X c*.	Apr. 10 ...	163	+47	....	Apr. 10, 1869. Traces on Apr. 9. ?If connected with XXI b; no intermediate meteors.	,,
XI a*.	Apr. 11 ...	193	+11	Extended; unexact	Apr. 11, 1869; no traces on adjacent nights: belongs to the same family as the two next.	,,
S$_4$.	Apr. 1–15 .	185	+22	....	....	Heis.
S$_5$.	Apr. 20 ...	199	+14	....	....	,,
M$_8$.	Apr. 20 ...	160	+49	....	Apparently belonging to the same family as XX c and XXI b.	Heis.]
XI b*.	Apr. 14 ...	167	+47	....	Apr. 14, 1868 and 1869. Connected by no meteors with XX c, among many observed on intermediate nights.	Schiaparelli.
III a*.	Apr. 25 ...	142	+53	Well-determined and exact.	Apr. 25, 1868. Appears to have no connection with any other meteoric shower.	,,
V a*.	Apr. 30–May 1.	237	+35	....	Apr. 30, 1867 and 1868... } Apparently connected or identical with the two next.	,,
		237	+35	....	May 1, 1868 }	
Q$_2$.	Apr. 23–June 4.	235	+50	....	....	R. P. Greg.]
Q$_1$.	May 1–31 .	232	+27	....	....	Heis.]
XIII a*.	June 13–14	280	+35	Well-defined	June 13, 1869. On this and previous evening some meteors from direction of Vega (Zezioli). June 14, 1869. Perhaps identical or of the same system with the next.	Schiaparelli.
W.	May 6–June 20.	280	+39	....	....	R. P. Greg.]

adiant-points contained in the former and omitted in the present list (see Report for 1870, p. 98.)

. 6.	Feb. 6	183	+56 }	....	....	Schiaparelli.
12.	Apr. 13 ...	231	+27 }			
16.	May 22 ...	232	+25 }			
18.	June 30 ...	240	+19 }			

many of the foregoing radiant-points, although separated from each other in position, or ights in which no intermediate meteors were observed, nevertheless possess in common features of very close resemblance, they are regarded by Professor Schiaparelli

as forming, in some cases, distinct meteor-systems or families of radiant-points, of which the principal, occurring in the first half of the year, may be grouped as follows:—

Families or groups of Radiant-points.

Symbol.	Date.	Position. α.	Position. δ.	General centre.	Reference.	Symbol.	Date.	Position. α.	Position. δ.	General centre.	Reference.
II *a*.	Jan. 6 ...	199°	+58°	Between η and ζ Ursæ Majoris.	Schiaparelli.	XIX *a*.	Mar. 31–Apr. 2.	261°	+48°	Near π Herculis.	Schiaparelli.
III *b*.	,, 12 ...	197	+59			XIX *b*.	Apr. 2–3	259	+38		
IV *d*.	,, 19 ...	200	+58			XX *a*.	Apr. 9 ...	255	+36		
V *a*.	,, 21 ...	205	+49			XX *b*.	Apr. 9 ...	246	+46		
V *b*.	,, 24 ...	200	+56			[QH$_1$.	Mar. 15–Apr. 23	268	+25	In Cerberus.	R. P. Greg.]
VI *a*.	,, 25–27	205	+47								
VI *b*.	,, 29 ...	198	+54								
IV *a*.	Jan. 18...	232	+36	Between α Coronæ and δ Boötis.	Schiaparelli.	XXI *a*.	Apr. 11 .	193	+11	Between δ and ε Virginis	Schiapa.
IV *c*.	,, 19...	220	+40			[S$_4$.	Apr. 1–15	185	+22		Heis.]
VI *c*.	,, 28...	236	+25			[S$_5$.	Apr. 20 .	199	+14		Heis.]
VI *d*.	,, 30...	225	+34			XX *c*.	Apr. 10 .	163	+47	....	Schiaparelli.
VI *e*.	,, 31...	221	+28			XXI *b*.	Apr. 14 .	167	+47	....	
						[M$_8$.	Apr. 20 .	160	+49	....	Heis.]

Should the effect of planetary perturbations, which retarded the return of Halley's comet in the year 1859 nearly one month from the time of its perihelion passage, as calculated by D'Alembert and Clairault, also explain the wide difference between the separate coils of spiral meteoric streams apparently encountered by the earth in the meteor-systems of which the above groups or families of radiant-points appear to present unmistakable examples, a new field of investigation in meteoric astronomy, and of future observation and research, is beginning to unfold itself in these new and interesting discoveries.

2. *On Comets and Meteors*, by Professor Kirkwood, Indiana University, U.S. (read before the American Philosophical Society, November 19, 1869). In an able treatise on "Meteoric Astronomy," already noticed in these Reports (for 1868, p. 418), a short Appendix (B) at the end of the volume on "Comets and Meteors" expresses the views on their connexion which Professor Kirkwood communicated, so long ago as July 1861, to the 'Danville Quarterly Review' for December in that year. "Different views are entertained by astronomers in regard to the *origin* of comets, some believing them to enter the solar system *ab extra*, others supposing them to have originated within its limits. The former is the hypothesis of Laplace, and is regarded with favour by many eminent astronomers. . . . . Now, according to Laplace's hypothesis, patches of nebulous matter have been left nearly in equilibrium in the interstellar spaces. As the sun in his progress approaches such clusters, they must, by virtue of his attraction, move towards the centre of our system, the nearer portions with greater velocity than the more remote. The nebulous fragments thus drawn into our system would constitute comets; those of the same cluster would enter the solar domain at periods not very distant from each other. . . . If we adopt Laplace's hypothesis of the origin of comets, we may suppose an almost continuous fall of primitive nebular matter toward the centre of our system—the drops of which, penetrating the earth's atmosphere, produce *sporadic* meteors, the larger aggregations forming comets. The disturbing influence of the planets

may have transformed the original orbits of many of the former as well as of the latter into ellipses. It is an interesting fact that the motions of some luminous meteors (or *cometoids*, as, perhaps, they might be called) have been decidedly indicative of an origin beyond the limits of the planetary system. But how are the phenomena of *periodic* meteors to be accounted for in accordance with this theory?

"The division of Biela's comet into two distinct parts suggests several interesting questions in cometary physics. The nature of the separating force remains to be discovered; 'but it is impossible to doubt that it arose from the divellent action of the sun, whatever may have been the mode of operation. A signal manifestation of the influence of the sun is sometimes afforded by the breaking up of a comet into two or more separate parts, on the occasion of its approach to the perihelion'*. No less than six such instances are found distinctly recorded in the Annals of Astronomy, viz.:—1. Ancient bipartition of a comet.—*Seneca*. 2. Separation of a comet into a number of fragments, 11 B.C.—*Dion Cassius*. 3. Three comets seen simultaneously pursuing the same orbit, A.D. 896.—*Chinese Records*. 4. Probable separation of a comet into parts, A.D. 1618.—*Hevelius*. 5. Indications of separation, 1661.—*Hevelius*. 6. Bipartition of Biela's Comet, 1845–46.

"In view of these facts it seems highly probable, if not absolutely certain, that the process of division has taken place in several instances besides that of Biela's Comet. May not the force, whatever it is, that has produced one separation again divide the parts? And may not this action continue until the fragments become invisible? According to the theory now generally received, the periodic phenomena of shooting-stars are produced by the intersection of the orbits of such nebulous bodies with the earth's annual path. Now there is reason to believe that these meteoric rings are very elliptical, and in this respect wholly dissimilar to the rings of primitive vapour which, according to the nebular hypothesis, were successively abandoned at the solar equator; in other words, that the matter of which they are composed moves in *cometary* rather than in *planetary* orbits. May not our periodic meteors be the *débris* of ancient but now disintegrated comets, whose matter has become distributed round their orbits?"

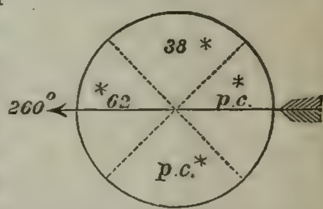
These views, announced in the year 1861, were afterwards completely established by the calculations of Professor Newton and Professor Schiaparelli regarding the real orbital velocities of shooting-stars, proving them to move, generally, in parabolic, or *cometic*, rather than in *planetary* orbits; and by the astonishing discovery in the year 1866, by Professor Schiaparelli, of the almost absolute identity of the orbit of Tuttle's Comet (III. 1862) with that of the August, and of the orbit of Temple's Comet (I. 1866) with that of the November meteor-stream, supposing (as the researches of Professor Newton and Professor Adams amply prove) that the latter, and presumably also the former of those meteor-clouds revolve in elliptic orbits of such considerable length, as not to differ much from the comets in their times of revolution. In his communication to the American Philosophical Society, Professor Kirkwood retraces the recent researches of Hoek, Leverrier, and Schiaparelli respecting the probable circumstances of the introduction of comets and periodical shooting-stars *ab extra* into the limits of the planetary system. The disturbing force by which their cosmical orbits were converted into elliptic ones of short periods (it is found in harmony with the preceding theory) was probably the overpowering attraction of one of the larger planets near to which the cosmical bodies first entered the limits of the solar system.

* Grant's 'History of Physical Astronomy,' p. 302.

In the following Table Professor Kirkwood compares together the aphelion distances of the several known comets of short periods with the mean distances of the several larger planets from the sun:—

Ordinal Number.	Comets.	Aphelion distance.		Ordinal Number.	Comets.	Aphelion distance.	
1.	Encke's ...	4·09	Mean distance of Jupiter from the sun 5·20.	1.	Peter's (1846, VI.)......	9·45	Saturns's mean distance 9·54.
2.	1819, IV....	4·81		2.	Tuttle's (1858, I.)	10·42	
3.	De Vico's...	5·02					
4.	Pigott's (1783)	5·28		1.	1867, I....................	19·28	Uranus's mean distance 19·18.
5.	1867, II. ...	5·29		2.	November Meteors......	19·65	
6.	1743, I.....	5·32		3.	1866, I....................	19·92	
7.	1766, II. ...	5·47		1.	Westphal's (1852, IV.).	31·97	Neptune's mean distance 30·04.
8.	1819, III...	5·55		2.	Pons' (1812)	33·41	
9.	Brorsen's .	5·64		3.	Olbers' (1815)............	34·05	
10.	D'Arrest's .	5·75		4.	De Vico's (1846, IV.)...	34·35	
11.	Faye's	5·93		5.	Brorsen's (1847, V.) ...	35·07	
12.	Biela's	6·19		6.	Halley's	35·37	

It is also evident that the passage of the solar system through a region of space comparatively destitute of cometic clusters would be indicated by a corresponding paucity of comets. Such variations of frequency are, indeed, found not only in the records of comets, but also of meteoric showers which have been accidentally recorded, the greater number of the latter having been observed during the five centuries between 700 A.D. and 1200 A.D., and again in those following A.D. 1700, suggesting that during the former and, perhaps, again during the present period the solar system is passing through a cosmical or meteoric cloud of very great extent,—not less, indeed, on the received speed of the sun's proper motion, than fourteen times the width of Neptune's orbit. Professor Kirkwood adds, in particular reference to the August meteor-system, "The fact that the August meteors, which have been so often subsequently observed, were *first* noticed in 811 [see M. Quetelet's Catalogue of Star-showers] renders it probable that the cluster was introduced into the planetary system not long previously to the year 800. It may be also worthy of remark that the elements of the comet of 770 A.D. are not very different from those of the August meteors and of the third comet of 1682"*. With regard to the sun's passage through a meteoric cloud of the above-considered dimensions and constitution it is noticed that the number of cometary perihelia found in the two quadrants of longitude towards and from which the sun is moving is 159, or 62 per cent., and that of perihelia in the two other quadrants is 98, or 38 per cent., showing their tendency to crowd together about the direction of the sun's proper motion in space. The large excess of



* The interval between the perihelion passage of 770 and that of 1862 is equal to 9 periods of 121·36 years. Oppolzer's determination of the period of 1862, III., is 121·5 years. Hind remarks that the elements of the Comet of 770 are "rather uncertain," but says "that the general character of the orbit is decided." It may be worthy of remark that a great meteoric shower, the exact date of which has not been preserved, occurred in 770.

the number of the cometary perihelia closest to the sun in the forward quadrants, relatively to the direction of his proper motion in space, is also regarded as indicating the direction of the sun's motion through the meteor-cloud in a manner which the facts of observation evidently corroborate.

3. *On the Periods of certain Meteoric rings.* By Professor Kirkwood (read to the American Philosophical Society, March 4, 1870).—According to the computed elements of the Comet I. 1861 (by Oppolzer), first shown by Dr. Edmund Weiss (Astron. Nachr. no. 1632) to agree very closely with those of the April meteor-stream, its periodic time of revolution is 415·4 years. On the other hand, Professor Kirkwood points out that, without accepting a shorter periodic time of revolution, the former April displays recorded in ancient times do not agree with the time of revolution of the comet. Adopting a period of about 28⅓ years for the cycle of returns of the April shower, the whole of the dates of its appearance selected by Professor Newton as agreeing well with those of its most recent appearance in the present century are represented with perfect accuracy by the following scheme:—

Dates of former appearances.	Interval in years.		
From B.C. 687 to B.C. 15	672·000=24	periods of	28·000 years each.
B.C. 15 to A.D. 582	597·000=21	„	28·429 „
A.D. 582 to A.D. 1093·714 (between 1093 and 1096)	511·714=18	„	28·429 „
A.D. 1093·714 to 1222·143	28·429= 1	„	28·429 „
A.D. 1222·143 to 1803	680·857=24	„	28·369 „

The periodical time of 28⅓ years corresponds to an ellipse whose major axis is 18·59, and whose aphelion distance is very nearly equal to the mean distance of the planet Uranus. A remark of Mr. Du Chaillu is here believed to be rightly recalled, that he observed the April meteors in the equatorial parts of Africa almost as brilliant, and leaving streaks more enduring than those of the great November meteor-shower (of which he was also an observer in England, in the year 1866). If the date of Mr. Du Chaillu's observation was about the year 1860, a corroboration of Professor Kirkwood's cycle of 28⅓ years repeated twice since the great display of those meteors in the year 1803 would be thence derived. The April meteor-shower was also sufficiently bright in the year 1863 to make its approach to an epoch of maximum brilliancy in about that year a somewhat probable conjecture.

Among the formerly recorded star-showers which appear to have certainly been connected with the December meteor-system, Professor Kirkwood points out a notice of such an occurrence in the year A.D. 901. Others are found to have taken place in the years 930, 1571, 1830, 1833, and 1836, with an apparent maximum in the year 1833, when as many as ten meteors were seen simultaneously. Finally, pretty abundant displays of the shower were observed in the years 1861, 1862, and 1863, with a probable maximum in the year 1862. These dates indicate a period of about 29⅛ years, thus—

901 to 930	1	period of	29·000 years.
930 to 1571	22	„	29·136 „
1571 to 1833	9	„	29·111 „
1833 to 1862	1	„	29·000 „

A third meteoric shower, that of the 15th–21st of October, presents, again, a similar period of revolution. The recorded dates of apparitions which correspond in the times of their appearance with the present meteor-showers of the 15th–21st of October are the years A.D. 288, 1436 and 1439, 1743, and 1798, on each of which occasions a great number of shooting-stars were

seen. The periodic time of $27\frac{1}{2}$ years is well indicated by these dates, thus:—

A.D. 288 to 1439	42	periods of 27·405	years each.
1439 to 1743	11	„ 27·636	„
1743 to 1798	2	„ 27·500	„

"If these periods are correct, it is a remarkable coincidence that the aphelion distances of the meteoric rings of April 18th–20th, October 15th–21st, November 14th, and December 11th–13th, as well as those of the comets 1866 I., and 1867 I. are all nearly equal to the mean distance of Uranus."

4. *Beiträge zur Kenntniss der Sternschnuppen*, von Dr. Edmund Weiss (Sitzungsberichte of the Imperial Academy of Vienna for January 16, 1868) presents a short summary of the mathematical problems required to be solved in the determination of the parabolic orbit, and the actual relative speed of the meteors' course in the atmosphere, from the known position of the radiant-point; and shows how approximate calculations of the velocities of shooting-stars have led to discoveries, in proving certain periodical meteor-currents to be intimately connected with comets of which the orbits have recently been determined*.

5. *The Fuel of the Sun*, by W. Mattieu Williams, F.C.S. (8vo, 222 pp. Simpkin and Marshall).—An attempt to explain convulsions of the sun's surface by planetary disturbances of a universal atmosphere collected in greatest density about the larger bodies of the solar system, and agitated by tides arising from their several attractions, is the theory for the establishment of which a collection of the greatest interest of recent observations of solar physics has been brought into a small compass by the author of the work, and is well directed to explain the chief phenomena of solar physics. The corona is regarded (Chapter XIII.) as originating in solar projectiles driven from its surface with eruptive violence. In the following chapter the source of meteorites is conjectured to be the solar projectiles which thus pass beyond the boundaries of the zodiacal light; some of which being confined to revolve in two principal orbits outside of that luminary, and in several intermediate zones of irregularly and more thinly scattered projectiles, may be regarded as giving rise to the August and November, as well as to other minor and more or less regular meteoric displays. Somewhat more important speculations and descriptions of the meteorology of the moon and planets, as well as of the distribution of the nebulæ, suggesting the stellar origin of some of those bodies, occupy the greater portion of the remainder of the work.

* The velocity of the April meteors, or Lyraïds, of the 20th of April meteoric shower, relatively to the earth, is given in Dr. Weiss's list of radiant-points and relative velocities of cometary orbits, in the above paper, as 1·585, that of the earth in its orbit being unity. Adopting the value of 18·6 miles per second for the earth's mean orbital velocity, this gives the relative velocity of the Lyraïds, or April shower-meteors, 29·5 miles per second; very nearly that observed (30 miles per second) in the case of the only shooting-star of the shower doubly observed, as described in this Report, on the night of the 20th of April last.

Fifth Report of the Committee, consisting of HENRY WOODWARD, *F.G.S., F.Z.S.,* DR. DUNCAN, *F.R.S., and* R. ETHERIDGE, *F.R.S., on the Structure and Classification of the Fossil Crustacea, drawn up by* HENRY WOODWARD, *F.G.S., F.Z.S.*

SINCE I had last the honour to present a Report on the Structure and Classification of the Fossil Crustacea, I have published figures and descriptions of the following species, namely:—

DECAPODA BRACHYURA.

1. *Rhachiosoma bispinosa*, H. Woodw. Lower Eocene, Portsmouth.
2. —— *echinata*, H. W. Lower Eocene, Portsmouth.
3. *Palæocorystes glabra*, H. W. Lower Eocene, Portsmouth. All figured and described in Quart. Journ. Geol. Soc. vol. xxvii. p. 90, pl. 4.

DECAPODA MACRURA.

4. *Scyllaridia Belli*, H. W. London Clay, Sheppey. Geol. Mag. 1870, vol. vii. p. 493, pl. 22. fig. 1.

AMPHIPODA.

5. *Necrogammarus Salweyi*, H. W. Lower Ludlow, Leintwardine. Figured and described Trans. Woolhope Club, 1870, p. 271, pl. 11.

ISOPODA.

6. *Palæga Carteri*, H. W. Lower Chalk, Dover, &c. Geol. Mag. 1870, vol. vii. p. 493, pl. 22. fig. 1.
7. *Præarcturus gigas*, H. W. Old Red Sandstone, Rowlestone, Herefordshire. Trans. Woolhope Club, 1870, p. 266.

MEROSTOMATA.

8. *Eurypterus Brodiei*, H. W. Quart. Journ. Geol. Soc. 1871, August. Trans. Woolhope Club, 1870, p. 276.

PHYLLOPODA.

*9. *Dithyrocaris tenuistriatus*, M'Coy. Carboniferous Limestone, Settle, Yorkshire.
10. *Dithyrocaris Belli*, H. W. Devonian, Gaspé, Canada.
11. *Ceratiocaris Ludensis*, H. W. Lower Ludlow, Leintwardine.
12. *Ceratiocaris Oretonensis*, H. W. Carboniferous Limestone, Oreton, Worcestershire.
13. *Ceratiocaris truncatus*, H. W. Carboniferous Limestone, Oreton, Worcestershire.

Figured and described in the Geol. Mag. 1871, vol. viii. p. 104, pl. 3.

14. *Cyclus bilobatus*, H. W. Carboniferous Limestone, Settle, Yorkshire.
15. —— *torosus*, H. W. Carboniferous Limestone, Little Island, Cork.
16. —— *Wrightii*, H. W. Carboniferous Limestone, Little Island, Cork.
17. —— *Harknessi*, H. W. Carboniferous Limestone, Little Island, Cork.
*18. —— *radialis*, Phillips. Carboniferous Limestone, Settle, Yorkshire, Visé, Belgium.
*19. *Cyclus Rankini*, H. W. Carboniferous Limestone, Carluke, Lanarkshire.
[*20. —— "*Brongniartianus*," De Kon. Carboniferous Limestone, Yorkshire, Belgium.]
21. *Cyclus Jonesianus*, H. W. Carboniferous Limestone, Little Island, Cork. (These latter figured and described in the Geol. Mag. 1870, vol. vii. pl. 23. figs. 1–9.)

[Those marked with an asterisk have been already figured, but have been redrawn and redescribed in order to add to or correct previous descriptions.

Thus, for example, "*Cyclus Brongniartianus*" proves upon careful examination to be only the hypostome of a Trilobite belonging to the genus *Phillipsia*. *Dithyrocaris tenuistratus* is identical with *Avicula paradoxides* of De Koninck, &c.]

Since noticing the occurrence of an Isopod, *Palæga Carteri*, from the Kentish, Cambridge, and Bedford Chalk, Dr. Ferd. Roemer, of Breslau, has forwarded me the cast of a specimen of the same crustacean from the Chalk of Upper Silesia. This, together with the example from the Miocene of Turin, gives a very wide geographical as well as chronological range to this genus.

A still more remarkable extension of the Isopoda in time is caused by the discovery of the form which I have named *Præarcturus* in the Devonian of Herefordshire, apparently the remains of a gigantic Isopod resembling the modern *Arcturus Baffinsii*.

I have also described from the Lower Ludlow a form which I have referred with some doubts to the Amphipoda, under the generic name of *Necrogammarus*.

Representatives both of the Isopoda and Amphipoda will doubtless be found in numbers in our Palæozoic rocks, seeing that Macruran Decapods are found as far back as the Coal-measures*, and Brachyurous forms in the Oolites†.

Indeed the suggestion made by Mr. Billings as to the Trilobita being furnished with legs (see Quart. Journ. Geol. Soc. vol. xxvi. pl. 31. fig. 1), if established upon further evidence, so as to be applied to the whole class, would carry the Isopodous type back in time to our earliest Cambrian rocks.

I propose to carry out an investigation of this group for the purpose of confirming Mr. Billings's and my own observations, by the examination of a longer series of specimens than have hitherto been dealt with. In the mean time the authenticity of the conclusions arrived at by Mr. Billings having been called in question by Drs. Dana, Verrill, and Smith (see the American Journ. of Science for May last, p. 320; Annals & Mag. Nat. Hist. for May, p. 366), I have carefully considered their objections, and have replied to the same in the Geological Magazine for July last, p. 289, pl. 8; and I may be permitted here to briefly state the arguments *pro* and *con*, seeing they are of the greatest importance in settling the systematic position of the Trilobita among the Crustacea.

Until the discovery of the remains of ambulatory appendages by Mr. Billings in an *Asaphus* from the Trenton Limestone (in 1870), the only appendage heretofore detected associated with any Trilobite was the hypostome or lip-plate.

From its close agreement with the lip-plate in the recent *Apus*, and also from the fact of the number of body-rings exceeding that attained in any other group save in the Entomostraca, nearly all naturalists who have paid attention to the Trilobita in the past thirty years have concluded that they possessed only soft membranaceous gill-feet, similar to those of *Branchipus*, *Apus*, and other Phyllopods.

The large compound sessile eyes, and the hard, shelly, many-segmented body, with its compound caudal and head-shield, differ from any known Phyllopod, but offer many points of analogy with the modern Isopods‡; and

* *Anthrapalæmon Grossartii*, Salter, Coal-measures, Glasgow.

† *Palæinachus longipes*, H. Woodw., Forest Marble, Wilts.

‡ It should always, however, be borne in mind that as the Trilobita offer, as a group, no fixed number of body-rings and frequently possess more than twenty-one segments, they

one would be led to presuppose the Trilobites possessed of organs of locomotion of a stronger texture than mere branchial frills.

The objection raised by Drs. Dana and Verrill to the special case of appendages in the *Asaphus* assumed by Mr. Billings to possess ambulatory legs, is that the said appendages were merely the semicalcified arches in the integument of the sternum to which the true appendages were attached.

A comparison, which these gentlemen have themselves suggested, between the abdomen of a Macruran Decapod and the Trilobite in question is the best refutation of their own argument.

The sternal arches in question are firmly united to each tergal piece at the margin, not along the median ventral line. If, then, the supposed legs of the Trilobite correspond to these semicalcified arches in the Macruran Decapod, they might be expected to lie irregularly along the median line, but to unite with the tergal pieces at the lateral border of each somite. In the fossil we find just the contrary is the case; for the organs in question occupy a definite position on either side of a median line along the ventral surface, but diverge widely from their corresponding tergal pieces at each lateral border, being directed forward and outwards in a very similar position to that in which we should expect legs (*not sternal arches*) to lie beneath the body-rings of a fossil crustacean. The presence, however, of semicalcified sternal arches presupposes the possession of stronger organs than mere foliaceous gill-feet; whilst the broad shield-shaped caudal plate suggests most strongly the position of the branchiæ. In the case of the Trenton *Asaphus* I shall be satisfied if it appears, from the arguments I have put forward, that they are *most probably* legs—feeling assured that more evidence ought to be demanded before deciding on the systematic position of so large a group as the Trilobita from only two specimens*.

With regard to the embryology and development of the modern King-Crab (*Limulus polyphœmus*), we must await the conclusions of Dr. Anton Dohrn before deciding as to the affinities presented by its larval stages to certain of the Trilobita, such relations being only in *general external form*. Dr. Packard (Reports of the American Association for the Advancement of Science, August 1870) remarks, "The whole embryo bears a very near resemblance to certain genera of Trilobites, as *Trinucleus*, *Asaphus*, and others;" and he adds, "Previous to hatching it strikingly resembles *Trinucleus* and other Trilobites, suggesting that the two groups, should, on embryonic and structural grounds, be included in the same order, especially now that Mr. E. Billings has demonstrated that *Asaphus* possessed eight pairs of 5-jointed legs of uniform size."

Such statements are apt to mislead unless we carefully compare the characters of each group. And first let me express a caution against the too hasty construction of a classification based upon larval characters alone.

Larval characters are useful guide-posts in defining great groups, and also in indicating affinities between great groups; but the more we become acquainted with larval forms the greater will be our tendency (if we attempt to base our classification on their study) to merge groups together which we had before held as distinct.

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have, as a matter of course, been considered as belonging to a much lower group than the Isopoda, in which the normal number of somites is seven. Whilst admitting the justice of this conclusion, we do not think it affords any good ground for rejecting the proposition that the Isopoda may be the direct lineal descendants of the Trilobita.

* One in Canada and one in the British Museum, both of the same species.

To take a familiar instance: if we compare the larval stages of the Common Shore-Crab (*Carcinus mœnas*) with *Pterygotus*, we should be obliged (according to the arguments of Dr. Packard) to place them near to or in the same group.

The eyes in both are sessile, the functions of locomotion, prehension, and mastication are all performed by one set of appendages, which are attached to the mouth; the abdominal segments are natatory, but destitute of any appendages.

Such characters, however, are common to the larvæ of many crustaceans widely separated when adult, the fact being that in the larval stage we find in this group what has been so often observed by naturalists in other groups of the animal kingdom, namely, a shadowing forth in the larval stages of the road along which its ancestors travelled ere they arrived from the remote past at the living present.

If we place the characters of *Limulus* and *Pterygotus* side by side, and also those of Trilobita and Isopoda, we shall find they may be, in the present state of our knowledge, so retained in classification.

I.

Pterygotus (Fossil, extinct).	*Limulus* (Fossil, and living).
1. Eyes sessile, compound.	1. Eyes sessile, compound.
2. Ocelli distinctly seen.	2. Two ocelli distinctly seen.
3. All the limbs serving as mouth-organs.	3. All the limbs serving as mouth-organs.
4. *Anterior* thoracic segments bearing branchiæ or reproductive organs.	4. *All* the thoracic segments bearing branchiæ or reproductive organs.
5. Other segments destitute of any appendages.	5. Other segments destitute of any appendages.
6. Thoracic segments *unanchylosed.*	6. Thoracic segments *anchylosed.*
7. Abdominal segments *free and well developed.*	7. Abdominal segments *anchylosed and rudimentary.*
8. Metastoma *large.*	8. Metastoma *rudimentary.*

II.

Trilobita (Fossil, extinct).	*Isopoda* (Fossil, and living).
1. Eyes sessile, compound.	1. Eyes sessile, compound.
2. No ocelli visible.	2. No ocelli visible.
3. Appendages partly oral, partly ambulatory, arranged in pairs.	3. Appendages partly oral, partly ambulatory, arranged in pairs.
4. Thoracic segments variable in number, from 8 even to 28, free and movable (animal sometimes rolling into a ball).	4. Thoracic segments usually seven, free and movable (animal sometimes rolling into a ball).
5. Abdominal series coalesced to form a broad caudal shield, bearing the branchiæ beneath.	5. Abdominal somites coalesced, and forming a broad caudal shield, bearing the branchiæ beneath.
6. Lip-plate *well developed.*	6. Lip-plate *small.*

Should our further researches confirm Mr. Billings's discovery fully, we may propose for the second pair of these groups a common designation, meantime we give the above as representing the present state of our knowledge.

Report of the Committee appointed at the Meeting of the British Association at Liverpool, 1870, *consisting of* Prof. Jevons, R. Dudley Baxter, J. T. Danson, James Heywood, *F.R.S.*, Dr. W. B. Hodgson, *and* Prof. Waley, *with* Edmund Macrory *as their Secretary, "for the purpose of urging upon Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison."*

Your Committee after their appointment held meetings in London, and agreed upon the following Memorial:—

"Uniformity *of* Plan *for the* Census *of the* United Kingdom.

"To the Right Honourable Henry Austin Bruce, M.P., &c. &c., Her Majesty's Principal Secretary of State for the Home Department.

"Memorial of the Committee of the British Association, appointed in Liverpool, September 1870, for the purpose of urging upon Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effectual comparison.

"Your memorialists beg respectfully to represent that the value of statistical information depends mainly upon the accuracy and expedition with which comparisons can be made between facts relating to different districts.

"They also consider that the ease and rapidity with which researches in the census tables can be made is one principal object to be held in view in determining the form of their publication. They therefore desire that not only should the enumeration of the people be conducted in all places in an exactly uniform manner, so far as is compatible with the terms of the several Census Acts, but that there should be no divergence in the modes of tabulating and printing the results. They wish that the tables for England, Scotland, and Ireland should form as nearly as possible one uniform and consistent whole.

"Your memorialists could specify a great many points in which there was divergence between the tables for 1861, but they will mention only a few of the more important cases.

"1. The detailed population tables of England, Scotland, and Ireland differ as regards the periods of age specified. The Scotch report gives twenty-one intervals of age, the Irish report generally twenty-two, and the English only thirteen. Either one-third of the printed matter in the Scotch and Irish tables is superfluous, or that in the English tables deficient.

"2. The classification of occupations is apparently identical in the three reports, but there is much real discrepancy between the Irish and English reports, rendering exact comparison difficult.

"3. In the Irish report there is no comparison and classification of occupations according to age, classification according to religions being substituted, although such a classification could not be made in England or Scotland.

"4. In the appendix to the English report appears a table (No. 56), giving

most important information as regards the numbers of the population at each year of age. Inconvenience has been felt from the want of similar information concerning the populations of Scotland and Ireland.

"5. In the appendix to the Irish report they find some interesting Tables (II., III., and IV.), to which there is nothing exactly corresponding in the other reports, so far as they have been able to discover.

"6. The tables, even when containing the same information, are often stated in different forms and arrangements, seriously increasing the labour of research.

"Your memorialists therefore beg to suggest:—

"I. That the principal body of tables relating to the numbers, age, sex, birthplace, civil condition, and occupation of the people should be drawn up and printed in an exactly identical form for the three parts of the United Kingdom.

"II. That while the Commissioners may with great advantage continue to exercise their free discretion in drawing up such minor tables as appear to have special interest for distinct localities, they should agree to prepare in a uniform manner such minor or summary tables as may be of importance as regards all the parts of the United Kingdom.

"III. That a general Index of Subjects should be prepared for the whole of the reports, appendices, and tables, so that an inquirer can readily ascertain where the corresponding information for different parts of the United Kingdom is to be found, without making, as hitherto, three independent searches through a mass of complex and almost unindexed information.

"It would appear that the officers engaged in superintending the Census of 1861 acted to a certain extent in concert and agreement.

"Your memorialists beg respectfully to request that those officers be instructed, on the present occasion, to confer with each other prior to drawing up the tables for 1871, with a view of preserving perfect uniformity in their operations, and avoiding all such divergencies in the three reports as are not required by the Census Acts or the essential differences of the three Kingdoms.

"Signed on behalf of the Committee, 8th December, 1870.

"W. Stanley Jevons, F.S.S.,
President of the Statistical Section of the British Association for the Advancement of Science, Liverpool, 1870.

"James Heywood, M.A., F.R.S.,
Vice-President of the Statistical Society.

"Jacob Waley, F.S.S.,
One of the Secretaries of the Statistical Society.

"Edmd. Macrory, M.A.,
Secretary of the Committee of the British Association for a Uniformity of Plan in the Census Tables of the United Kingdom."

The above memorial was immediately presented to the Right Hon. H. A. Bruce, M.P., Her Majesty's Principal Secretary of State for the Home Department, and has been by him referred to the Registrars General for their report thereon.

The returns of the Census having only recently been collected, too little time has as yet elapsed for the perfect arrangements of the tables to be completed, but your Committee have reason to believe that the recommendations contained in the above memorial will ultimately be, to a considerable extent, adopted by Her Majesty's Government.

Postscript.—Since the above Report was drawn up, the Committee have received a formal reply from the Home Office (dated 26th September, 1871), informing them that the Home Secretary "has desired the Registrar General for Scotland, and has requested the Lord Lieutenant to desire the Census Commissioners in Ireland, to frame their tables in conformity with those submitted by the Registrar General for England and Wales, and approved by Mr. Bruce, as far as circumstances will admit; and that with this view he has instructed the above-mentioned officers to place themselves in communication with the Registrar General for England and Wales."

Report of the Committee appointed for the purpose of Superintending the Publication of Abstracts of Chemical Papers. The Committee consists of Prof. A. W. Williamson, *F.R.S.,* Prof. H. E. Roscoe, *F.R.S.,* Prof. E. Frankland, *F.R.S.*

The Committee are glad to be able to announce that regular monthly reports of the progress of Chemistry have been published since April 1st, 1871, by the Chemical Society. These Reports have been rendered, as far as possible, complete by abstracts, more or less full, of all papers of scientific interest, and of the more important papers relating to applied chemistry. The abstracts have been made by chemists, most of whom are members of the Society, whose zeal for the science has induced them to undertake the work for the small honorarium which the Council has been able to offer. A numerous Committee of Publication has been formed, whose Members gratuitously undertake the revision of the proofs and a comparison of the abstracts with the original papers.

The Reports are edited by Mr. Watts, each monthly part being bound up with the corresponding number of the Chemical Society's Journal. Each volume will be furnished with a full index, and will give a complete view of the progress of Chemistry during the year.

The Committee feel that their thanks are due to all those gentlemen engaged in the work for having already so far succeeded in accomplishing a task of such difficulty and importance, and they confidently hope that their continued exertions will still further perfect the details of the scheme so as gradually to increase the usefulness of the Reports.

It is right to state that the funds of the Chemical Society available for the purpose of the Reports, although so opportunely aided by a grant of £100 from the British Association, were insufficient to defray the necessary expenses, and that voluntary contributions to the amount of upwards of

£200 have been received towards the cost of publication for the first year, up to April 1872.

There is good reason to believe that the expectations entertained of the usefulness of these Reports will be fully realized by their continuance on the present system, and that they will be found largely to conduce to the progress of the science wherever the English language is spoken.

Report of the Committee for discussing Observations of Lunar Objects suspected of Change. The Committee consists of the Rev. T. W. Webb *and* Edward Crossley, *Secretary.*

The Committee have much pleasure in presenting their first Report on the above subject. Though much attention has been given of late years to a large number of lunar objects, your Committee felt that they could not accomplish their purpose better than by confining their Report to the discussion of a limited and well-observed portion of the lunar surface. No person seeking to discover evidence of geologic change would be constantly travelling over the whole surface of our globe, but would of necessity confine his attention to a small area for a considerable period of time. This has been the course adopted on the moon. Plato, a vast crater, containing 2700 square miles, in 51° N. lat. and 10° E. long., has presented a most interesting and important variety of features, which we have endeavoured to photograph, so to speak, with pen and pencil, with a view, if not at once to obtain our ultimate object, at least to lay out the groundwork for future observers.

The Report has been carefully drawn up by Mr. W. R. Birt on behalf of the Committee. Time has only permitted the discussion of the observations of the bright spots and craterlets seen on the floor of Plato; whereas your Committee consider that it is equally important that the observations of the numerous streaks, with the faults and other peculiar features noticed on the floor and walls of this fine formation, should be likewise discussed, in order that something like a complete description of this object as observed at the present time may be presented to the Association for the use of future selenographers.

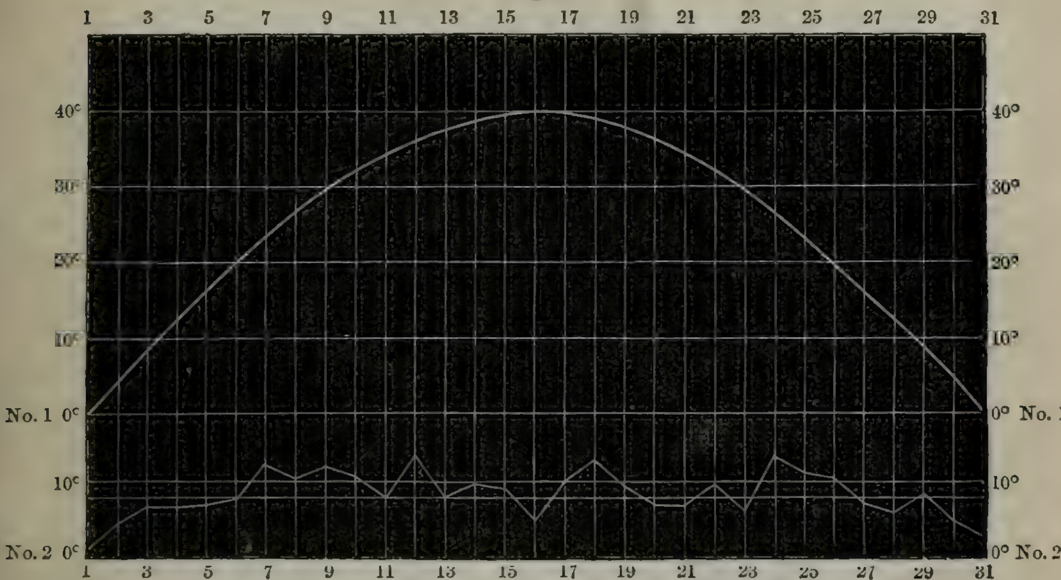
Your Committee would therefore request that a further grant of £20 may be placed at their disposal for this purpose during the ensuing year.

Report on the Discussion of Observations of Spots on the Surface of the Lunar Crater Plato. By W. R. Birt.

In executing the task confided to me of discussing certain observations of the spots on the lunar crater Plato, one of the first points which I deemed it important to ascertain was the effect which the intensity of the sun's light as a function of his altitude might produce on the visibility of the spots. The number of spots actually observed between April 1869 and April 1871 inclusive, amounted to 37, the greater portion (21) having been discovered in this interval. In order to become acquainted with phenomena possibly connected with an increase of light on the floor of the crater, the observations have been arranged under intervals of twelve hours, from sunrise to sunset on Plato, and a ledger formed for each interval, the number of which is 31. From these ledgers the results in Table II. have been deduced, viz. the *mean* number of spots visible during each interval, and the actual number of spots observed during each interval. For illustrating the results

the curves in fig. 1 have been projected. The first curve is that of solar altitudes at the moon, epoch the equinoxes, locality 50° north or south latitude. The second curve is that of the *mean* number of spots visible during each interval.

Fig. 1.



Curve No. 1. Solar altitudes. Latitude 50° at equinoxes.
Curve No. 2. Curve of mean number of spots visible each interval.

TABLE I. Solar Altitudes at Moon.

	Latitude 50°.									Latitude 55°.									
Interval.	Winter.			Equinoxes.			Summer.			Winter.			Equinoxes.			Summer.			Interval.
h	°	′	″	°	′	″	°	′	″	°	′	″	°	′	″	°	′	″	h
0	......	......	......	......	......	......	1	10	35	......	......	......	......	......	......	1	15	28	0
12	2	44	4	3	54	50	5	5	35	2	13	52	3	29	32	4	45	6	12
24	6	36	48	7	48	6	8	59	17	5	41	19	6	57	29	8	13	24	24
36	10	26	0	11	38	10	12	50	6	9	6	19	10	22	6	11	38	48	36
48	14	10	0	15	23	20	16	36	30	12	24	10	13	42	0	14	59	30	48
60	17	46	50	19	2	0	20	16	20	15	35	50	16	55	0	18	13	40	60
72	21	14	40	22	31	20	23	47	30	18	38	40	19	59	0	21	19	20	72
84	24	31	0	25	49	30	27	7	50	21	30	30	22	52	30	24	14	20	84
96	27	33	30	28	54	20	30	14	50	23	4	50	25	33	0	26	56	40	96
108	30	19	30	31	42	40	33	5	30	26	32	40	27	58	20	29	23	40	108
120	32	46	0	34	11	30	35	36	40	28	38	30	30	5	40	31	32	0	120
132	34	50	0	36	17	30	37	45	0	30	24	0	31	53	0	33	21	50	132
144	36	28	20	37	57	50	39	27	20	31	47	10	33	17	40	34	47	50	144
156	37	38	30	39	9	10	40	40	40	32	46	30	34	17	50	35	49	20	156
168	38	18	30	39	50	30	41	22	20	33	20	0	34	52	0	36	24	0	168
Mer.	38	27	51	40	0	0	41	32	9	33	27	51	35	0	0	36	32	9	Mer.

TABLE II. Ordinates of Curve of Spot frequency.

No.	Interval.	Altitude.	Mean.	Number.	Observations.
	h h	° °			
1.	0 to 12	— to 5	1·0	1	1
2.	12 „ 24	— „ 5	4·6	15	7
3.	24 „ 36	3 „ 9	5·9	14	6
4.	36 „ 48	7 „ 13	5·9	14	8
5.	48 „ 60	11 „ 17	6·4	15	9
6.	60 „ 72	15 „ 21	7·1	13	7
7.	72 „ 84	18 „ 24	12·0	27	7
8.	84 „ 96	22 „ 28	10·1	27	7
9.	96 „ 108	25 „ 31	11·6	27	9
10.	108 „ 120	28 „ 34	10·7	21	6
11.	120 „ 132	31 „ 36	7·5	13	4
12.	132 „ 144	33 „ 38	12·4	33	8
13.	144 „ 156	35 „ 40	7·4	17	5
14.	156 „ 168	37 „ 41	9·2	19	6
15.	168 „ Mer.	38 „ 42	8·5	19	8
16.	Mer. „ 168	42 „ 38	5·0	9	4
17.	168 „ 156	41 „ 37	9·3	21	9
18.	156 „ 144	40 „ 35	12·2	23	5
19.	144 „ 132	38 „ 33	9·1	25	8
20.	132 „ 120	36 „ 31	6·3	9	3
21.	120 „ 108	34 „ 28	6·0	8	3
22.	108 „ 96	31 „ 25	9·0	20	6
23.	96 „ 84	28 „ 22	5·2	12	5
24.	84 „ 72	24 „ 18	13·0	23	3
25.	72 „ 60	21 „ 15	11·0	21	4
26.	60 „ 48	17 „ 11	10·0	15	2
27.	48 „ 36	13 „ 7	6·3	11	3
28.	36 „ 24	9 „ 3	5·8	13	6
29.	24 „ 12	5 „ —	8·0	13	2
30.	12 „ 0	5 „ —	5·0	7	2
31.	— „ 12		3·0	3	1

We may regard the various maxima of the spot-curve as indicative:—First, of a greater number of observations during the intervals which furnish the maxima. It is true the column of observations may countenance this view; but it does not hold in all cases, neither are the greater number of observations so pronounced as the maxima of the curve. Second, of a clearer state of the earth's atmosphere than usual, enabling us to see more spots than when it is ordinarily translucent. This may to some extent explain the occurrence of maxima separated by several intervals, and probably those instances where we have a larger number of spots with a smaller number of observations. Third, of an actual increase of visibility of the spots themselves at different and widely separated epochs, the observations of such increased visibility falling at those intervals at which the maxima were recorded. The following are the epochs at which the greatest number of spots were observed corresponding with the maxima of the curve:—

First maximum. Interval 2. 1870, Jan. 10, 12 spots, 15 for the whole interval, from 7 observations.

Table III.

[The spots marked *s* were discovered previous to the commencement of these observations.]

No.	Interval.	Altitude.	0°	1°	2°	3°	4°	5°	6	7°	8°	9°	10	11°	12	13	14	15°	16	17°	18	19	20	21	22°	23	24	25	26	27	28	29	30°	31°	32	33	34	35	36	Sums.	Means.	Spots.
1	0 to 12	Under 5				1																			...		...													1	1·2	1
2	12 24	5		5		6	4	1	1	2		2		1						3		...	...			1		1		1	...		2	1	1					32	4·6	[illegible]
3	24 36	3 to 9		6		6	6	2				2	1	1		1	1			5			1		1								1		1					35	5·9	14
4	36 48	7 ,, 13		8		7	8	3	1			2		2			4		1	6		1				1		1					2			..				47	5·9	14
5	48 60	11 17	1	9		7	8	6	1			2		2			5		1	8		1						·	·		...	1	3			...	1			58	6·4	15
	Sums		1	28		27	26	12	3	2		8	1	6		1	1[illegible]		2	22		2	1	...	1	2		2		1	...	1	8	1	2		1			173		25
	Visibility		·04	1·0		[illegible]	[illegible]	·43	·11	[illegible]		·2[illegible]	·04	·21		·04	·36		·07	·79		·07	·04		·04	·07	..	·07		·04	..	·04	·29	·04	·07	...	·04					
6	60 to 72	15 21		[illegible]		[illegible]	[illegible]	5	3							2	5		3	7	1	1					..					1	1							5[illegible]	7·1	1[illegible]
7	72 ,, 84	18 ,, 24	1	[illegible]	2	[illegible]	[illegible]	[illegible]	2	1		4	2	3		1	5	1	4	7	2	1	1	1	2		2	3		...	...	2	4		3		2	..		84	12·[illegible]	2[illegible]
8	84 ,, 96	22 28	1	[illegible]	2	[illegible]	[illegible]	4	2	2	1	2	1	1		3	4	1	2	[illegible]	1	3	1	1	2			1		...		2	4		1		1			71	10·1	2[illegible]
9	96 ,, 108	25 31	1	9	1		[illegible]	[illegible]	[illegible]	1		5	1	4		2			[illegible]	9	2	2	2	1	2	1	1	2		...		1	6		2		1			104	11·6	2[illegible]
10	108 ,, 120	28 34	2	6		1	1	1	3					2		1	5		1	6	1	1	1	2	2		1	2		.			2		3					64	10·7	21
	Sums		[illegible]	3[illegible]	5	5	[illegible]	3[illegible]	1[illegible]	4	1	13	4	1[illegible]		9	27	[illegible]	[illegible]	36	7	8	5	5	8	1	4	8		...		6	17		9		4			373		2[illegible]
	Visibility		·14	1·[illegible]	·14	[illegible]	[illegible]	·53	[illegible]	·1[illegible]	·03	·3[illegible]	·11	·2[illegible]		·25	·75	[illegible]	[illegible]	1·0	·19	·22	·14	·14	·22	·03	·11	·22				·17	·47		·25		·11					
11	120 to 132	31 36		4		[illegible]	4	3				1		1		2	2		3	4		1								...			1		1	...				3[illegible]	7·5	13
12	132 144	33 38	2	6	2	8	9	[illegible]	3	5	1	5	1	[illegible]	2	2	1		4	8	2	2	2	1	4	3	3	5				1	5	1	4	1	1	1	1	112	12·4	33
13	144 156	35 40		5		6	5	2	1			1		1		1	1		3	5		1			..	1		1		...			2	1	1					37	7·4	17
14	156 168	37 41		[illegible]		4	6	5	2	2			1	1		1	5		4	5		2	1		3			3	..				2	1	1	...				55	9·2	19
15	168 Mer.	38 42		8		[illegible]	[illegible]	[illegible]	1	2		1	3	1		2			6	[illegible]		1		...	2		1	3					1	1						65	8·5	1[illegible]
	Sums		2	32	2	27	31	23	[illegible]	9	1	8	5	6	2	8	21		27	29	2	[illegible]	3	1	9	4	4	12				1	11	4	[illegible]	1	1	1	1	3[illegible]2	..	[illegible]3
	Visibility		[illegible]		·06	·84	[illegible]	·72	·22	·28	·03	·25	·16	·19	·06	·25	[illegible]		·63	·91	·06	·22	[illegible]	·03	·28	·12	·12	·37				·03	·34	·12	·22	·03	·03	·03	·03			
	Sums before Meridian		8	9[illegible]	[illegible]	9[illegible]	[illegible]	[illegible]	27	15	2	29	17	22	2	18	53	2	42	87	9	17	9	6	15	[illegible]	8	22		1		8	36	5	10	1	6	1	1	848		

Table IV.

16	Mer. to 168	42 to 37		4		4	[illegible]	2				1					1		1	3								1	..											2[illegible]	5·[illegible]	9
17	168 ,, 156	41 ,, 37	·	6		[illegible]		7	4	1		2		1		3	5		7	9	1	2			3	3		3					2	1	2					84	9·3	21
18	156 ,, 144	40 ,, 35	·	5		5	5	4	2	2		2		1	2	1	5		4	5	2	2	1		3	1	1	2					3	2			.			61	12·2	25
19	144 ,, 132	38 ,, 33		[illegible]	1	1	1	1	[illegible]	1		4	1	2		2	5		4	7	1	1			3	1	2	2	1		1		3		1	2	.			73	9·1	25
20	132 ,, 120	36 ,, 31				3	3	2									2	·	1	3					1			1 ..				...								1[illegible]	6·3	[illegible]
	Sums		2	2[illegible]	1	27	26	21	9	4		9	1	4	2	6	16		1[illegible]	27	4	5	1		1	5	3	9	1		1		5	3	3	2				25[illegible]		2[illegible]
	Visibility		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	·75	·32	·14		·32	·04	·14	·07	·21	[illegible]		·61	·96	·14	·18	·04	..	[illegible]	·18	·11	·32	·04		·04		[illegible]	·11	·11	·07				.....		
21	120 to 108	34 ,, 28		3		3	1					2		2					1	3													3			...	...			18	6·[illegible]	8
22	108 ,, 96	31 ,, 25	2	[illegible]		5	5	4	1	2		4		3		1	2	1	2	5	2	1			3			...					3		1	1	...	...	...	54	9·[illegible]	2[illegible]
23	96 ,, 84	28 ,, 22		[illegible]		3	5	2				1		1		1	1		1	3	1				2							...							...	26	5·2	12
24	84 ,, 72	24 ,, 18	1	3	1	3	3	2	3	1		2		1		1	3		1	3	1	1			2	1	1	2			...		1	1	1		.			39	15·0	23
25	72 ,, 60	21 ,, 15		4		3	4	4	1	1		2	1	2	1	3	3	1	2	3	1	3			2	...					...		1	1	1	...				44	11·[illegible]	21
	Sums		3	21	1	17	18	12	5	4		11	1	9	1	6	9	2	7	17	5	5			9	1	1	2		..			8	2	3	1 ..				181	...	2[illegible]
	Visibility		·14	[illegible]	·05	·81	·86	·57	·24	·19	.	·52	·05	·43	·05	[illegible]	·43	·09	·33	·81	·24	·24			·43	·05	·05	·09		..			·38	·09	·14	·05				......		
26	60 to 48	17 ,, 11		2	1	2	1	1	1	1		2		1				1		2									1	1	1			2			...			20	10·0	15
27	48 ,, 36	13 ,, 7	...	3		2	3	2	1			1		1			1			3	1						.	...	...				1 ...		...					19	6·3	11
28	36 ,, 24	9 ,, 3		1	.	5	2	2	2	2						2	2	·	2	5		1			1			...	...				3 ...			.	...			35	5·8	15
29	24 ,, 12	Under 5		2		2	1	1				1			1	1	1		1	2	1	1			1				...			.							...	16	8·[illegible]	13
30	12 ,, 0	,, 5		3		3						1				1				3	1					.			...				1						...	13	4·3	[illegible]
	Sums			1[illegible]	1	14	7	6	4	3		5		2	1	4	4	1	3	15	3	2			2 ...	...			1	1	1		5	2						103		23
	Visibility			[illegible]	[illegible]	·8[illegible]	·44	·3[illegible]	·25	·19		·31	...	·12	·06	·25	·25	·06	·19	·94	·19	·12	.		·12 ..			...	·06	·06	·06		·31	·12						..		
	Sums after Meridian		[illegible]	[illegible]	3	58	51	39	18	14		25	2	15	4	16	31	3	27	59	12	12	1		21	6	4	11	2	1	2		21	7	6	3				541	...	

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Second maximum. Interval 7. 1870, March 13, 17 spots, 27 for the whole interval, from 7 observations.

Third maximum. Interval 12. 1870, May 13, 27 spots, 33 for the whole interval, from 8 observations.

Third maximum. Interval 12. 1870, Jan. 15, 22 spots, 33 for the whole interval, from 8 observations.

Fourth maximum. Interval 19. 1869, Dec. 20, 19 spots, 25 for the whole interval, from 8 observations.

Fifth maximum. Interval 22. 1870, Nov. 11, 13 spots, 20 for the whole interval, from 6 observations.

Sixth maximum. Interval 24. 1870, Sept. 14, 16 spots, 23 for the whole interval, from 3 observations.

When we take the mean numbers of spots seen at each interval, the curve is comparatively flat, rising but little above the mean line of 7·9 spots visible at any interval, and this is about the mean number visible on any evening. The flatness of the curve is not accordant with an increase of spots dependent on an increase of solar altitude or greater angle of illumination, otherwise the apex would be much more decided. We may, however, trace from the number of spots actually seen and contributing to the maxima of the spot-curve, as well as from the observations adduced above, that the change of illuminating angle does exercise an influence on the appearance of spots, inasmuch as on a few occasions the largest number of spots have been seen with higher illuminations. The actual curve, however, derived from two years' observations is not sufficiently decided to refer the appearances of the spots to this agency.

By dividing the whole of the twelve hourly intervals into six series or groups, and taking spot No. 1 as the standard of comparison, we have the data for computing Tables III. and IV. containing the visibilities of each spot for each group of intervals: sunrise, or 0 to 60 hours, altitudes 0° to 17°; 60 to 120 hours, altitudes 15° to 34°; 120 hours to meridian passage, altitudes 31° to 42°; meridian passage to 120 hours, altitudes 42° to 31°; 120 to 60 hours, altitudes 34° to 15°; and 60 to 0 hours, or sunset, altitudes 17° to 0°. From the results in these Tables, Table V. has been formed, in which we have a bird's-eye view of the visibilities during the luni-solar day. Generally the visibilities are low during the first 60 hours, *i. e.* compared with spot No. 1, the smaller spots are but seldom seen; and this is so far indicative of solar light in some way developing or bringing the spots into visibility. During the next 60 hours some spots have risen considerably in visibility, while others have been seen more frequently during the afternoon hours of the luni-solar day. The numbers are, however, too irregular to allow us to conclude that the smaller and less frequently seen spots are influenced in their visibility by further changes of illuminating angle beyond their first development; and this is very strikingly manifested by the curves which these numbers furnish; for example, the diurnal curves of spots Nos. 5, 14, and 16 in fig. 2 generally agree in exhibiting greater visibilities from 60 hours to meridian passage, while spots Nos. 9 and 11 are more frequently seen from 120 to 60 hours before sunset. These, as well as the peculiarities of the other curves, strongly suggest that the variations of visibility of certain spots are not to any great extent dependent upon an increase of intensity of solar light, but rather upon some agency more particularly connected with the spots themselves. It is important to remark that another series of observations *may* furnish totally different diurnal curves, should the variations in visibility depend upon local lunar action.

In nearly every case the spots seen during the first 60 hours of the luni-solar day have increased *during the day* in visibility, *i. e.* they were seen less frequently during this group of intervals than during the succeeding sixty hours. This increase, however, has not been regular, which it would have been from changes of illuminating angle alone, some spots having been seen, as before stated, more frequently during the second group of intervals, while others have declined in visibility and not attained their maxima until the period 120 to 60 hours before sunset. The diurnal curves of spots Nos. 14, 5, and 16 in the first category, and those of Nos. 9 and 11 in the second, have already been referred to; that of spot No. 22 (fig. 3) differs from the others by its showing an increase of visibility from sunrise to 120 hours before sunset. The visibilities of many spots are lower during the last 60 hours of the luni-solar day.

Fig. 2.

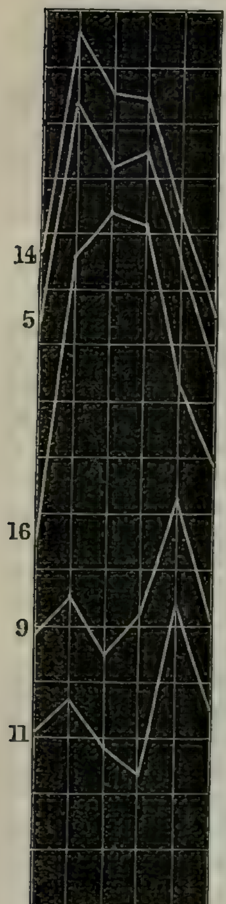
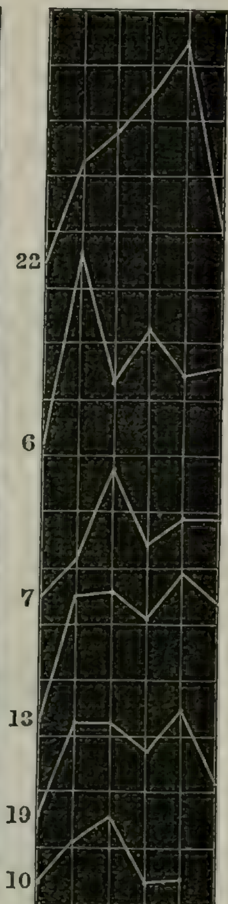


Fig. 3.



Diurnal Curves of Visibility. Spots on Plato.

The curves of visibility during the luni-solar day are essentially different from the curves of visibility as deduced from the observations of twenty-four lunations, although both lead to the same result; and from both a very important conclusion may be drawn, viz. that upon assuming other agencies to be in operation than changes of illuminating angle, such as present activity, the epochs at which such activity was manifested varied to such an extent, and were so far separated from each other in time, as to coincide, in the case of spots Nos. 14, 5, and 16, with the period in the luni-solar day of 60 to 120 hours after sunrise, while the activity manifested by spots Nos. 9, 11, and 22 occurred at a later period of the luni-solar day, 120 to 60 hours before sunset. So far as the variations of visibility of spots Nos. 14, 5, 16, 9, 11, and 22 are concerned, they do not appear to depend exclusively on changes of illuminating angle, even if a certain intensity of solar light contributes generally to render the spots visible.

While the four craterlets Nos. 1, 3, 30, and 17 are visible during the whole of the luni-solar day, the spots on their sites are seldom seen until the sun attains an altitude of about 30°, and then they appear as "bright round disks;" and this characteristic attaches as well to the craterlets as to other spots when the sun attains this altitude. With altitudes between 30° and 40° a different class of phenomena is manifested; the sharp and distinct cha-

TABLE V.

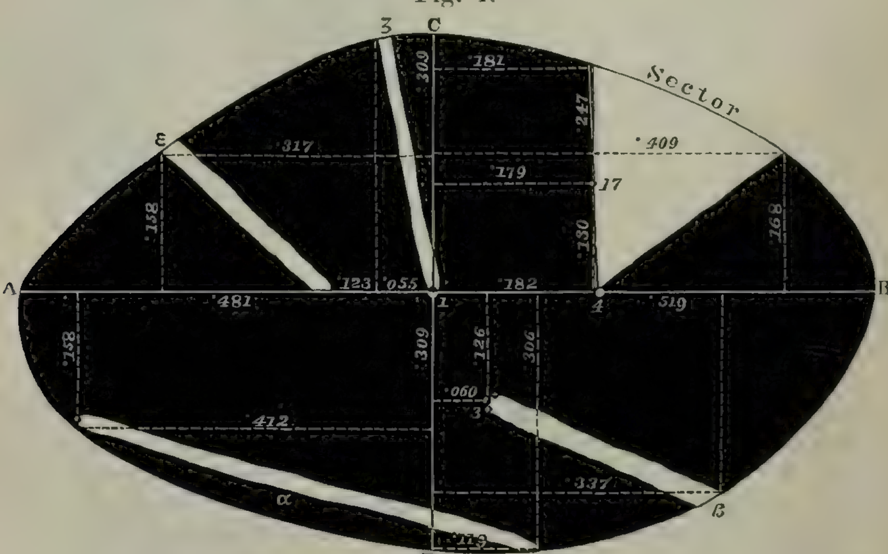
	Visibility.					
No.	h h 0 to 60	h h 60 to 120	h 120 to Mer.	h Mer. to 120	h h 120 to 60	h h 60 to 0
0.	·04	·14	·06	·07	·14	
1.	1·00	1·00	1·00	1·00	1·00	1·00
2.	. . . .	·14	·06	·04	·05	·06
3.	1·04	1·00	·84	·96	·81	·87
4.	·93	1·00	·97	·93	·86	·44
5.	·43	·83	·72	·75	·57	·37
6.	·11	·47	·22	·32	·24	·25
7.	·07	·11	·28	·14	·19	·19
8.	. .	·03	·03	. .	. .	. .
9.	·29	·36	·25	·32	·52	·31
10.	·04	·11	·16	·04	·05	. .
11.	·21	·28	·19	·14	·43	·12
12.	. .	. .	·06	·07	·05	·06
13.	·04	·25	·25	·21	·29	·25
14.	·36	·75	·66	·64	·43	·25
15.	. .	·06	. .	. .	·09	·06
16.	·07	·56	·63	·61	·33	·19
17.	·79	1·00	·91	·96	·81	·94
18.	. .	·19	·06	·14	·24	·19
19.	·07	·22	·22	·18	. .	·12
20.	·04	·14	·09	·04	. .	. .
21.	. .	·14	·03	. .	. .	. .
22.	·04	·22	·28	·36	·43	·12
23.	·07	·03	·12	·18	·05	. .
24.	. .	·11	·12	·11	·05	. .
25.	·07	·22	·37	·32	·09	. .
26.	. .	. .	. .	·04	. .	·06
27.	·04	. .	. .	. .	. .	·06
28.	. .	. .	. .	·04	. .	·06
29.	·04	·17	·03	. .	. .	. .
30.	·29	·47	·34	·29	·38	·31
31.	·04	. .	·12	·11	·09	·12
32.	·07	·25	·22	·11	·14	. .
33.	. .	. .	·03	·07	·05	. .
34.	·04	·11	·03	. .	. .	. .
35.	. .	. .	·03	. .	. .	. .
36.	. .	. .	·03	. .	.	. .

racter of the craterlets is no longer observed. Some put on a hazy appearance, and they all assume the same aspect as those spots which have not been observed as craterlets. This state of things continues until the declining latitudes approach the limit at which the crater form was lost in the advancing day, then it once more appears accompanied by a disappearance of most of those spots which came into visibility as the sun rose higher. We have an analogous phenomenon to this in the well-known crater *Aristarchus*. Shortly after sunrise its outline is sharp and distinct, while its interior is partly covered with a well-marked shadow and partly glowing in strong sunlight. As the sun rises above its horizon these characteristics are lost; the ridge extending from it to Herodotus becomes brighter, and to some eyes, and with some instruments, it is confounded with the interior, the whole appearing as a very vivid brush of light. The exact solar altitude at which the

change takes place is as yet undetermined; but there can be no question that it is of the same nature as that of the appearance of the spots on Plato greatly intensified.

The result of the discussion may be briefly stated as being very strongly suggestive of the existence of present lunar activity, the exact nature of which requires further and more extensive observations to determine. Intimately connected with the spot-changes are the variations of appearance and intensity of reflective power of the streaks and markings on the floor of Plato. In the observers' and other notes which form the Appendix to this Report will be found allusions to the connexion between the spots and streaks; but it manifestly requires a similar discussion of the streaks and markings to arrive at a definite conclusion on the subject. Most of the observers have furnished observations of these interesting phenomena, so that a discussion of them could at once be proceeded with if it should be the pleasure of the Association to carry on the inquiry. The principal results of the discussion of the spot-observations relative to visibility, irrespective of solar altitudes, and treated in pairs of lunations from April 1869 to November 1870, based on 1594 observations during 20 lunations, are contained in Lunar Map Circular VIII.; and some further remarks occur in a paper on the subject, published in the Philosophical Magazine, March 1871. This discussion, on an entirely different principle to that employed in the preparation of the present Report, and leading to a similar result, tends to confer on both a character in which confidence may be placed, for either without the other is incomplete; together they point to present lunar action as the originating agency producing the phenomena.

Fig. 4.



Although measurements for position of such delicate objects as the spots on Plato are difficult to execute, Mr. Gledhill has succeeded in obtaining three sets of micrometrical measures, on September 13 and December 9, 1870, and on May 1, 1871, a combination of which has enabled me to draw the outline of the crater, and to insert from these measurements four streaks and the sector as seen generally by Mr. Gledhill. The streaks are ζ, ϵ, α, and β. The streaks ζ and ϵ are rather westward of their places as given on

the tinted plate in the 'Student' of April 1870, p. 161. The spots whose positions have been determined by measures are Nos. 1, 4, 3, and 17. The effect of the measures is to bring them closer together and more towards the centre of the crater than in the printed plans. On each occasion that the measures were made, a diameter of the crater passing through spots Nos. 1 and 4, from A to B, was measured, also one at right angles to this from C to D, passing through No. 1. All the remaining measures of spots and streaks were referred to these diameters, spot No. 1 being the origin of the coordinates, and the longest diameter being considered as unity. The ratios of the means of the measures were determined to be as follows:—

			Spot or Streak.	Parallel to A B.	Parallel to C D.
Longest diameter A to B	=	1·000	No. 3	·060	·126
			,, 17	·179	·130
Spot No. 1.			Sector east end.........	·409	·168
To east border B	=	·519	,, west end.........	·181	·247
,, west border A......	=	·481	Both on border.		
,, south border C ...	=	·309	Streak ζ.................	·055	...
,, north border D ...	=	·309	,, ε.................	·317	·158
,, spot No. 4	=	·182	,, base on A B	·123	...
			Streak α W. end	·412	·158
			,, α E. end	·119	·306
			,, β on border ...	·337	

In order to plot the spots that have been laid down by alignment and estimation, it is necessary to align with the measured spots, and particularly with objects on the border, a process that will be adopted in the preparation or a monogram of Plato.

APPENDIX.

Observers' Notes.

These are arranged in each interval of 12 hours according to season, so as to give increasing altitudes of the sun from $\odot - ☊ = 270°$. Winter in the northern hemisphere.

Interval 0 to 12 hours.

1869, Oct. 13, 7^h ($\odot - ☊ = 76° 24'·8$, Oct. 12^d 21^h).—*Ten* hours after the epoch of sunrise at the equator in E. long. 4° 0'·6, the first streak of sunlight was seen by Mr. Gledhill to fall on the floor of Plato *through* the gap in the west wall between B. & M.'s peaks δ and ϵ, the W. extremity lying on or near the fault from N.W. to S.E., and bringing into visibility the craterlet No. 3, which is seen earliest of all the spots. Mr. Gledhill gives the sun's azimuth equal to 87° 31', the altitude being equal to the angle formed by the height of the depression in the wall between the peaks above the point of the floor on which the sun's rays first impinge.

Interval 12 to 24 hours.

1870, July 6, 8^h.—*Twelve hours and a half* after epoch of sunrise at the equator, E. long. 4° 11'·5, $\odot - ☊$, July 5, 19, 30 = 354° 54'·4. Mr. Gledhill again witnessed the first streak of sunlight fall on the floor of Plato, and observed spot No. 3 just within it, and remarked that the streak lay parallel with the longest diameter, and did not incline from No. 3 as it did in January. [On the 13th of October, 1869, at 7^h, Mr. Gledhill remarked that the streak was a little inclined to the N., and not quite parallel with the rim.] At 9^h of July 6, 1870, Mr. Gledhill remarked that a line through the two gaps or

breaks in the S. and N. borders passed through the western ends of the earliest streaks of light thrown on the floor. This line appears to be coincident with the great fault crossing Plato. With reference to this I have the following note:—"This phenomenon, the western extremities of the streaks falling in a line with the breaks in the N. and S. borders, was well observed in January 1870. An elevation of the ground in the direction of this fault has been seen. It would, however, appear that differences in the lengths of the streaks would depend not on any unevenness of the ground, but on the relative depths of the gaps in the W. border."

1870, January 10, 2^h to 8^h.—From ten to sixteen hours after epoch of sunrise at the equator, E. long. 4° 6′·1, ⊙ – ☊, Jan. 9, 16^h, equal to 170° 27′·8. This was by far the finest observation of sunrise on Plato by no less than seven observers, viz. Messrs. Gledhill, Pratt, Elger, Neison, Birmingham, Joynson, and Birt. Mr. Gledhill's record is so full and so interesting that a reproduction of it will convey a vivid impression of the progress of illumination of a lunar formation as the sun rises upon it.

Jan. 10, 2^h. Cloudless. Terminator just on the E. border of Plato; can just see the outline of the crater, which now lies in deep shadow. On the E. side the lofty steep wall just N. of a triangular formation marked II $E\psi^2$ glowed intensely in the solar rays.

3^h. The E. wall from the great breaks in the S. and N. borders appeared as a bright narrow band. The curved outline of the N.E. border was bright, sharp, and narrow, but the lower slope within could not be seen. I could fancy that the W. part of the floor is, if possible, deeper in shadow than the E. half. [This phenomenon has often been witnessed, and has been attributed to the reflection of the strong light of the eastern interior from the dark floor. Upon attentively contemplating this degradation of shadow near its eastern boundary, it will often be seen that it is not simply a reflection from the floor, but apparently the illumination of a something *above* the floor.—W. R. B.]

3^h 45^m. A bright narrow broken line was seen between the two breaks on the E. and N.E. The outline of II $E\psi^2$ is not yet visible.

4^h 18^m. At this moment (12 hours 18 minutes after epoch) the first streak of light fell upon the floor. Within it and near its western extremity was seen No. 3 as two elevated objects, very near each other, but quite distinct. I could not detect shadow between them after hard gazing, although it was easily seen to the N.E. of the lower object. The streak was three times the breadth of the two objects together where it enclosed them, and it became broader near the N.E. border of Plato; it was brightest about and to the west of No. 3, and inclined a little downwards at the E. end. * * * The two components of No. 3 are of the same size apparently, are equally but not very bright; they lie nearly E. and W. of each other, but the E. component is a very little to the N. of the other.

4^h 30^m. The streak widens. I could not detect motion in it. I now carefully placed the wire on the great gap in the west border; the line passed along the axis of the streak. The west angle of the streak is not sharp, but rounded, and lies a little beyond No. 3. The lower of the cones of No. 3 touches the lower edge of the streak. It now assumed a fan shape, being broadest at the E. end, which is now more than halfway to the E. border.

4^h 40^m. The streak is now much wider. I think I see a minute elevation a little to the E. of No. 3 and in the streak. The two components of No. 3 are now bright and sharp, with shadow on the east. Another streak has been barely visible or suspected for a few minutes; it lies to the S. of the

former and near the S. border. It runs parallel with the northern streak, is about half its length, and has its western extremity over a point a little E. of No. 3. It is narrow, and extremely faint and difficult. A minute or two later it was seen better, also a still fainter and narrower line to the north of it, which is parallel with it and the northern streak. The most southern streak produced to the E. would graze the southern edge of II $E\psi^2$.

$4^h\ 50^m$. Now the shadows from the W. wall take shape. The south shadow, which extends up to the S. border, goes directly into the gap at the S. edge of II $E\psi^2$. The next pointed shadow to the N. of this goes direct to the middle of II $E\psi^2$; it is extremely pointed at its E. end for more than half its length, and is suddenly wider at the W. end. [This appears to indicate that the peak which throws the shadow is very needle-like.] I cannot be quite sure that this shadow for the next 10^m or 15^m really extended up to the E. border. It became so faint and narrow and line-like that it could not be well seen near the border. Then, again, the floor for some distance (say a distance equal to the width of II $E\psi^2$) lay in rather dark shadow. The floor between the shadows was not bright up to the E. border of Plato; all along the foot of the E. slope a dark shadow lay, and this interfered with an exact determination of extremities of shorter shadows from the W. wall. The next shadow to the north was a broad parallel-sided belt, which proceeded to the E. border as such. Its upper or S. edge extended to the N. end of II $E\psi^2$, and its lower or N. edge cut the border of Plato just below, or to the north of II $E\psi^2$. A line through No. 3 to the gap in the S.E. border cuts the W. angles of the two southern bright spaces between the shadows.

5^h. No. 3 lies on the lower edge of the lowest bright space or upper edge of the lowest shadow. The shadow still clings to or is in contact with No. 3, and either extends to the E. of it, or No. 3 throws a shadow to the E. The floor along the E. border is still dusky; it is brightest at that part in line with No. 3,

$5^h\ 5^m$. A very fine narrow shadow is now seen to stand off from the shadow below and in contact with No. 3; it is this which touches No. 3.

$5^h\ 15^m$. The upper shadow is now clearly pointed, and falls short of the border. [This is probably the shadow of the peak between B. & M.'s γ and δ.] I still see a minute elevation just to the N.E. of No. 3. It is now just on the tip of the lowest pointed shadow, and about halfway from 3 to the N.E. border. [This spot is No. 32; it was discovered in streak β by Mr. Elger on December 15, 1869.—W. R. B.]

$5^h\ 45^m$. Floor at the foot of the E. border is still dark, except at the extreme N. The long broad shadow is now retiring from the E. border, and is seen faintly bifurcated; the lowest or northern fork is the longer, but this broad shadow still seems to have its N. and S. edges parallel.

6^h. Now the dark shadow on the S. border breaks up, and a fine pointed shadow separates from its northern side, which if produced goes quite into the gap at the southern edge of II $E\psi^2$. The bright W. angle above this shadow goes back towards the W. until under the great gap in the S. border. The great central shadow is now easily seen bifurcated; the lower peak is the longest, and reaches nearly up to the east border. The tip of the shorter shadow to the N. reaches just to No. 3; the next to the N. is rather longer.

$6^h\ 20^m$. The object to the N.E. of 3 (32) is easy, elevated, and bright. Now 4 is seen, also a large elevated object (7) about halfway from it to the N. extremity of II $E\psi^2$, and on this line.

$6^h\ 30^m$. The great S. band of shadow goes straight into the gap at the S. end of II $E\psi^2$. The E. portion of the floor for some distance from the foot

of the slope is still dusky. The shadow of the N.E. component of No. 3 is easy, and lies to the N.E. A line from the lower edge of the shadow in the great gap of the west border along the lower edge of the central shadow goes into the gap at the N. end of II E♃2. This shadow is now finely bifurcated; the lower or northern peak is the longer.

8^h. Spot No. 1 is now seen as a large striking object. It seems to be in the path of the *upper* fork of the central shadow, and looks like the shadow of one of Jupiter's satellites on the disk. [In Mr. Birmingham's sketch of May 19, 1869, ☉— ☊ =286° 37'·3, the upper or southern fork of the central shadow is longest, while in the present series of observations the northern is the longest. This is not a solitary instance of variation in the shadow of this peak. Mr. Birmingham is in agreement with Mr. Gledhill in referring spot No. 1 to the upper or southern fork. In my paper on the spots and shadows of Plato (Transactions of Sections, p. 17, 'Report of British Association for the Advancement of Science,' 1869), I remark that Rosse and Birmingham have drawn No. 1 with the shadow of δ just receding from it. Challis's shadow of δ terminates by a straight line; neither fork was visible, for he carefully measured the two angular points. Rosse drew the termination of the shadow as from *two* pinnacles upon the summit, with No. 1 between them. These variations are doubtless azimuthal; nevertheless they are of great importance, as we hope presently to show.]

$8^h 5^m$. Spot No. 1 is a large, lofty, very prominent cone. Close to the N.E. component of No. 3, and to the N.E. of it, is seen a black shadow *curved to the N.E.*, with a bright elevated object close to the curve. I see the two components of No. 3 as bright distinct objects; then, close to the N.E. foot of the N.E. component, comes a large circular shadow quite black, embracing a bright object to the N.E.

$8^h 15^m$. Spot No 4 is already getting rather difficult and hazy, although it lies far away in the bright eastern floor. Spot No. 17 is now seen just on the lower edge of the uppermost pointed shadow. No. 1 is bright and large, free from the long shadow. Shadow still lies on the eastern floor at the foot of the slope. Mr. Pratt, the same evening, Jan. 10, noticed a peculiar feature of the eastern part of the floor corroborative of Mr. Gledhill's observation of the dip to the foot of the east border. He says, "A peculiar feature of the eastern part of the floor in sunlight observed. Between what was probably the eastern margin of the sector b and the foot of the interior slope of the E. rim was a decidedly darker tint, as if that part of the floor was lower than the rest, and perhaps falling towards the border; the western margin followed very closely the form it would have if the whole space between the sector b and the border were depressed." In my own record, Jan. 10, $4^h 48^m$, the Crossley equatorial 7·3-in. aperture, eye-piece No. 4, power 122, with slot, I say:—"The S. spire of sunlight apparent; it is directed towards the middle of II E♃2. Neither of the spires of light reach the border, indicating the floor to dip near the border."

Mr. Gledhill summarizes his observations, under the head of "points determined," as follows:—

First. The position, size, alignment, and order of development of the streaks [of sunlight, as distinguished from those that make their appearance afterwards] which first fall on the floor. They are evidently the solar rays passing through the gaps on the border.

Second. The floor on the E. at the foot of the inner slope lies in shadow more or less deep until the giant shadows from the W. border have retreated westward beyond the centre of the crater.

Third. That spots Nos. 1, 3, 17, the object halfway between No. 4 and the E. border (7), the object halfway $\pm$ between No. 3 and the E. border (32), the object (if any) just to the E. of No. 3 (31), and the object S.W. of No. 1 at a considerable distance away are all elevated objects.

[Some time subsequently to these observations I received from Mr. Gledhill a drawing of nine *crater cones* seen on Jan. 10, 1870. They were Nos. 1, 3, 30, 4, 7, 9, 11, 17, and 32. I have not received any confirmation of the object a considerable distance S.W. of No. 1.—W. R. B.]

Fourth. The order in time of the appearance of the shadows.

Fifth. The time to a minute when light first falls on the floor.

[The discussion of the observations by *intervals* shows that the sun's light first falls upon the floor of Plato from ten to thirteen hours after the sun has risen at 4° 6′·1 of E. long. on the equator according to season: a simple computation of the epoch of sunrise at this longitude and ⊙ − ☊ will be a guide to ascertain the illumination of Plato within twenty-four hours of the epoch.—W. R. B.]

Sixth. The interval between the appearance of light on the floor and the distinct perception of the shadows from the W. border is about twenty-five or thirty minutes.

Seventh. The great northern streak of sunlight is seen some fifteen minutes before the southern streaks are detected. This may be caused either by difference in elevation of the gaps in the W. border, or difference in level of the floor, or both may unite to produce the effect.

What can cause the duskiness of the eastern floor except depression of the floor?

1870, Jan. 10, $9^h\ 0^m$. Mr. Elger saw spot No. 1 close to the shadow of the peak situated on the S. of the great gorge or opening in the W. wall. At $9^h\ 10^m$ the N. peak of this shadow was about clearing it; at the same time spot No. 4 could just be seen. Mr. Elger remarked that the shading round spot No. 1 was much *darker* than the central portion of the floor, and that this dark shading could be traced in an easterly direction to about one fourth of the distance between the spots 1 and 4: "this," says Mr. Elger, "would appear to indicate *a fall in the surface of the floor* from No. 1 towards the E. in section" (fig. 5). Schröter, if I remember rightly, alludes to some observations indicating similar irregularities in the floor. From Mr. Elger's observation, combined with one of Mr. Gledhill's to be noticed under Feb. 9, 1870, it would appear that spot No. 1 is situated on the ridge marking the great fault. (See interval 24^h to 36^h.)

Fig. 5.

1870, May 8, 8^h to 10^h. Close of first interval of twelve hours. Epoch $7^d\ 21^h\ 20^m$. Mr. Elger writes, "On the evening of the 8th, between 8^h and 10^h, I had a fine view of sunrise; the air was remarkably steady; shadows and minute details seen to perfection."

1870, May 18. Mr. Elger writes:—"*Re* your statement as to the dip of the floor. Is there reliable evidence that the N.E. and S.E. areas of the floor are lower near their respective borders than towards the spotless central area? In January last I saw spot No. 1 in contiguity with the shadow of No. 2 peak (western wall); the surface of the floor east of No. 1 was then, of course, seen under very oblique light. Judging from the shading and general aspect of the surface in the neighbourhood of No. 1, there appeared to be a *very rapid* fall from spot No. 1 to spot No. 4; if this be so, the stem of the 'trident' would be a depression in the surface."

1870, April 9. Twenty-three hours after epoch of sunrise at 4° 4′·7 on

equator, E. long., Mr. Elger records spots Nos. 1 and 17 in contiguity with shadows of high peaks on west wall [γ and δ]: Nos. 1, 3, 4 very plain [seen also by Mr. Pratt], 17 faint, 25 only glimpsed, 7 suspected; no markings seen. Mr. Pratt records on same day shadows of γ, δ, and ϵ on floor nearly similar to 1869, Nov. 12, excepting that δ showed a *second point* south of chief one, and that of ϵ did not exhibit a cleft.

The importance of such careful observations as those which have furnished the data for this interval cannot admit of question. The determination of the epoch at which the floor first becomes illuminated, as compared with the epoch of an easily computed phenomenon (sunrise at a given longitude on the equator), places at once within our reach the means of ascertaining when the appearances witnessed during the interval 10 to 24 hours after sunrise, at 4° E. long. on the equator, will be repeated*. This is, however, a small result compared with the forms and progressions of the shadows; for by their aid, especially if well sketched, and their lengths carefully measured, or even estimated in parts of those of the three measured peaks γ, δ, and ϵ, the distance of the west wall from the terminator being at the same time ascertained, the irregularities of the west wall at sunrise, and by a similar process those of the east wall at sunset, may be obtained with tolerable precision by B. & M.'s method described in 'Der Mond,' § 65, p. 98, and in the Report of the Lunar Committee of the British Association, 'Report,' 1867, p. 15. We have thus the power, by multiplying such observations, of becoming intimately acquainted with the breaks and gaps, the elevations and towering pinnacles of the wall, and are in a position for handing down to our successors details that may enable them to detect changes, if such should occur, of sufficient magnitude to become perceptible. The shadows which I enumerated on Jan. 10, 1870, were six,—the longest γ, one between γ and δ, δ with its *two* peaks or saddle form, one south of ϵ, and ϵ. Mr. Joynson, of Liverpool, gives in his drawing of the same date two peaks to δ. The irregularities both of the floor and border have come out by these observations with marked distinctness, and tend greatly to settle for the present epoch the main features. If, however, changes are in progress, they may be, as on the earth, extremely slow.

The appearances recorded on January 10, 1870, being so different to that witnessed by Bianchini, August 16, 1725, the following translation, by my friend Mr. Knott, from Bianchini's work 'Hesperi et Phosphori Nova Phenomena' (Romæ, 1728), will doubtless be read with interest:—

"Under the auspices of the Cardinal de Polignac, two large telescopes, 94 and 150 Roman palms long, by Campini, were prepared and erected, and on the 16th of August, 1725, the following observations of Plato were made.

"Although on that night we were only able to turn the telescope 150 palms long, on the moon we detected, in the lunar spot named Plato, a phenomenon not previously observed. The moon was at the time a little past its first quadrature with the sun, which it had attained on the previous day, and the spot Plato fell on the periphery of solar illumination, where is the boundary of light and darkness in the lunar hemisphere exposed to the sun. The whole of the very elevated margin, which on all sides surrounds the spot like a deep pit, appeared bathed in the white rays of the sun. The bottom of the spot, on the other hand, was still in darkness, the solar light not yet reaching it; but a track of ruddy light, like a beam, crossed the

* The longitudes of the terminator at 60° N. latitude on the equator, and at 60° S. latitude, Greenwich, midnight, during the lunation, are given monthly in the 'Astronomical Register.'

middle of the obscure area, stretching straight across it from one extremity to the other, with much the same appearance as in winter in a closed chamber the sun's rays admitted through a window are wont to present, or as they are seen in the distance when cast through openings in the clouds, or like comets' tails at night in a clear sky stretched out at length in space, as we remember to have seen in the one which in the years 1680 and 1681 was so conspicuous to all Europe. This appearance, never before seen by me in this or any other lunar spot, is represented in the figure which I give below.

Fig. 6.

"1, 2. The lunar spot named Plato, and the ruddy ray of the sun thrown across its dark floor from the margin of the spot 1, white and turned towards the sun. It was thus observed at Rome on the Palatine Mount, Aug. 16, 1725, at $1\frac{1}{2}$ hour after sunset, with the 150-palm telescope of J. Campini.

"It is proposed to astronomers and physicists, for their consideration and judgment, whether this is to be taken as an indication of an aperture piercing the border of the spot which is turned towards the sun, through which opening the rays are cast and appear as through a window; or whether it is rather to be thought that they are refracted rays, which are bent from the top of the border towards the bottom, and appear of a ruddy tint as they are wont to do in our own atmosphere at sunrise and sunset, and so give reason for admitting the existence of some denser fluid like an atmosphere surrounding the lunar globe."

I have the following remarks on the above, dated June 4, 1867:—

"Bianchini appears to have been one of the *earliest* observers who noticed 'detail' more particularly. Hevel, Riccioli, Cassini, and others aimed more at delineating the entire surface, which of course included much detail that is becoming more and more valuable every day; still such observations as Bianchini's, recorded in his 'Hesperi et Phosphori,' are of great value, especially as the appearances described and delineated could not find place in a more general work."

Schröter, in his 'Selenotopographische Fragmente,' vol. i. p. 334, §§ 256, 257, refers to the observation of Bianchini, and also to one of Short's in 1751, April 22. It would appear that Bianchini's suggestion of an aperture or *hole* in the W. rim of Plato was not verified by Short, who seems to have observed

the shadows of the three peaks γ, δ, and ϵ of B. & M., which are represented by Schröter in t. xxi. The shadows of these and other peaks on the W. wall have been very frequently observed of late years.

I am not aware that Bianchini's observation has been verified. The peculiar appearance which he has delineated depends not only on libration, but also on the angle which the terminator makes with the meridian; for it is clear that the *direction* of the terminator must form a tangent to a line passing equally through the depression in the wall to produce the appearance seen by Bianchini; and it is highly probable that it is of very rare occurrence, *as seen from the earth*, the variation in the angle of terminator with meridian being as much as 3°.

While transcribing the above (April 22, 1871) I have considered the Bianchini phenomenon more closely. During the year 1870 the opportunities for observing sunrise on Plato were comparatively numerous, and certainly not the slightest appearance of Bianchini's streak was detected; on the other hand, the positions of the earliest rays of sunlight on the floor have been determined, with some degree of precision, for the portion of the luni-solar year during the period of the observations. If the configuration of the W. wall is *different* now from what it was in Bianchini's time, the phenomenon may be explained by the supposition that the gap or pass N. of the peak δ was lower than at present, and has been raised by "landslips" on one or both sides, which are of extensive occurrence on the moon as recognized by Nasmyth; the absence of further observations by Bianchini *on the same evening*, however, leaves the matter in doubt.

Short records, in the Phil. Trans. for 1751, p. 175, that on April 22, 1751, he saw a streak projected along the flat bottom of Plato. Soon after he saw another streak parallel to the first, but somewhat lower [or northerly], which in a very short time divided into two. He found a gap in the wall opposite the first streak, and also one in the direction of the lower one.

Not only is Bianchini's observation at variance with modern observations, but Short's also. The order of appearance of the streaks of sunlight on the floor on Jan. 10, 1870, is, first, the broad streak through the wide gap; second, the southern streak north of the peak γ. The appearances of Short's streaks were in the reverse order.

The following record of observations by Schröter on July 30, 1789, at $9^h\ 48^m$, kindly translated by Mr. Gledhill, will illustrate Mr. Elger's observation on January 10, 1870:—

'Selenotopographische Fragmente,' § 250, vol. i. p. 329. "A different, more beautiful, and more magnificent view of Plato is obtained when, with the rising sun, the first traces of an extremely faint twilight are seen on the grey floor of the crater, and when the first beams of light are thrown over the mountains into the plain below. This view of Plato, which lasts only for a few minutes during the slow monthly rotation, and for which one may wait for a year and yet not see it, I saw on the 30th of July, 1789, $9^h\ 48^m$. As in the 8th figure of t. xxi., the terminator had advanced from W. to E. as far as α, β. To the W. of this the greatest part of the border lay in the light of day [or on the day side], and only the small portion to the E. of α, β was illuminated on the night side. The whole inner grey surface, on the contrary, was still hidden by the shadows of the lofty mountains on the border, and on the S. border there was also a low spot filled with shadow. While I was observing the shadows of the inner surface with power 161, I became aware of something to the E. of the middle of the floor, as if the dark surface were in a kind of fermentation. A few seconds later I saw here in

two places an extremely distinct unveiling or brightening *which closely resembled a very faint twilight.* Both places appeared dark, blackish, and contrasted so slightly with the other night-shadows, that at first I was uncertain whether or not I perceived a real difference in the obscurity. Meanwhile, after a few seconds both the light-spots became somewhat brighter, changed their form continually, until they soon became larger and notably brighter, and assumed the appearance given in fig. 8; and as no very marked change occurred while the observation was being made, I was by this time able to sketch them in their present clearer colour and increased size; but even yet they appeared a dark grey, so that, according to my arbitrary scale and a very approximate estimation, they were placed at only $\frac{1}{4}°$, or at most $\frac{1}{2}°$.

"Doubtless these present but always very dark colours were half-shadows, and were found there because in these two places only a part of the rising sun was visible over the irregular elevations on the western border; and these half-shadows I have often seen in the course of my observations when the terminator passes across grey surfaces. Soon after, the surface threw off the mask of night, and in a few minutes I could distinguish the line-like shadows lying across the whole floor thrown by the peaks on the western wall. If one, however, compares the shape of these two somewhat bright spots on the map with the position and shadows of the west border, and reflects that these bright spots, as I saw them, were surrounded by the shadows of night on the east, there can no longer be any doubt (if a different reflection of the light has no share in the matter) that the floor is not perfectly flat, but that these two places are somewhat more elevated; and with this supposition the observations given before quite agree."

The following notes have been kindly furnished by Mr. Pratt, relative to the foregoing description of sunrise:—

"Jan. 10, 3^h. On 1870, March 10, I have notes of the same phenomenon, which I believe I forwarded at the time, recording the inability I experienced to rid myself of *the idea that I was witnessing a true twilight.* My observation of it extended over twenty-five minutes, at the end of which time I perceived the faintest trace of the formation of the spires."

"Jan. 10, 4^h 18^m, spot No. 3. Query. Is *the brightest spot* of the streak, here mentioned as seen inclined to the north of No. 3, and I presume in close proximity to it, my spot No. 30? As far as I can understand the localities are identical."

"Jan. 10, 4^h 50^m, shadow of peak γ. On a similar occasion I have observed the thin thread of the shadow lying across II $E^{\psi 2}$, and have watched it slowly shortening and *travelling down* the interior slope of the rim, and had a good view of it lying on the floor just in contact with the foot of the slope."

"Jan. 10, 8^h, shadow of peak δ. I do not remember to have ever seen the shadow of δ otherwise than with the northern fork the longest."

On Bianchini's light-streak Mr. Pratt remarks:—"Bianchini's ruddy spire of light, which he observed at Rome, 1725, Aug. 16, and thought to be sunlight shining through an aperture in the west wall, would the want of achromaticity in his 150-palm telescope account for the colour? Still his unique view may prove valuable some day; and it is stimulating to perseverance on our part to multiply observations with our comparatively luxurious instruments to find such unwieldy telescopes capable of so much in the hands of a careful observer. I wonder if the crater G on the west exterior slope was recorded so long since, as its clean-cut form, as I have sometimes seen it, is suggestive of recent formation, and its locality such as to easily account for the filling-up of the aperture Bianchini supposed."

[The crater G is not seen in Bianchini's drawing of 1725, August 16, nor in that illustrating his observations of 1727, August 23 and September 22.—W. R. B.]

Mr. Pratt remarks, that in Short's observation of 1751, April 22, the first streak of sunlight was on the upper part of the floor, followed soon after by a parallel streak somewhat lower. "It is important," says Mr. Pratt, "to learn what *kind* of telescope Short used during the observation; for as he was *chiefly* a maker of the Gregorian form, and as that construction does not invert the image, it may be possible his term *lower* may mean southerly instead of northerly, thus being in accord with modern observations."

"The very interesting translation of Schröter's notes of 1789, July 30, and his discovery of something on the eastern half of floor, as if a kind of fermentation was going on, and his discovery a few seconds later of an unveiling or brightening, closely resembling twilight, remind me," says Mr. Pratt, "very forcibly of my own observations before mentioned. The half-shadows of Schröter also remind me of what I have very often seen, as he describes; but I cannot understand his explanation of them. As far as I can see, half-shadows presuppose an atmosphere; and a well-authenticated course of observations of them would be good proof of the latter's presence."

[If by the term "half-shadow" be meant the penumbral fringe of every true shadow, the rays of light emerging from opposite limbs of the sun, crossing beyond the object casting the shadow and then diverging, will fully explain such a fringe. In the case of the sun rising above the mountains, the reverse phenomenon occurs, viz. a gradual darkening fringe skirting the illuminated surface arising from less and less light arriving from the sun's disk; a true twilight is occasioned by the particles of an atmospheric medium being illuminated by the sun's rays while the luminary is below the horizon, and such I believe I have on several occasions witnessed.—W. R. B.]

Interval 24 to 36 hours.

1870, May 9. Mr. Gledhill describes spot No. 1 as easy; a fine sharp crater, with raised walls, much black shadow within, the east inner slope bright: he also records 3 and 17 as presenting the same appearance as No. 1. On October 3, at about 12^h earlier illumination, Mr. Gledhill did not observe the crater character of these objects, but describes them as elevated objects. This is remarkable, as on Oct. 3 the moon's latitude was 1° to 2° S., while on May 9 it was 3° N., libration carrying Plato further from the eye, yet the crater character was more distinct. Mr. Elger records No. 17 as seen by glimpses.

As regards spots 13 and 19, the following remarks of Mr. Elger are interesting:—"The northern portion of the floor, including streak α, was noted as equally light; the streak could not be traced." Mr. Gledhill writes, α not to be distinguished from the bright floor all along the north border. Mr. Elger found the same locality "all light on the 10th."

1870, February 9. Mr. Gledhill first saw spot No. 4, its bright W. wall only. He says, "This object seems to have *lower* walls than 1, 17, or 3." Mr. Gledhill writes: "For a few minutes I saw what appeared to be a very low ridge running from N. to S. across the floor of Plato. It runs from the N. border to spot 3, then curves to No. 1, and again bends back to the E. and reaches No. 17, and thence goes on to the S. border." [The low ridge mentioned by Mr. Gledhill is, so far as I know, *new*. It is not coincident with the great fault from N.W. to S.E. From a drawing subsequently sent to me by Mr. Gledhill, it would indicate a fracture, having its origin at spot

No. 1, diverging N.E. and S.E. to spots Nos. 3 and 17, and extending from them in opposite directions to the N. and S. borders.] At 5.30 Mr. Gledhill recorded that spot No. 4 is already *indistinct*; there is a dull yellow patch about it. No. 3 at this early stage of illumination Mr. Gledhill found to be single; he looked in vain for the other two adjacent spots, Nos. 30 and 31.

1870, Oct. 3. Mr. Gledhill records Nos. 1, 3, 17, and 30 as elevated objects. Mr. Elger found no trace of 3.

1870, March 11. Mr. Gledhill describes spots Nos. 1 and 3 as bright, circular.

Interval 36 to 48 hours.

1870, April 10. Mr. Gledhill records spot No. 1 as a large, sharp, circular crater, with internal shadow on W. side; also Nos. 3 and 17 as circular craters. Mr. Elger records Nos. 16 and 25 as frequently glimpsed.

1870, July 7. Mr. Whitley observed Nos. 1, 3, and 17 as craterlets, 4 a white spot, and glimpsed No. 11 very faint. On the same evening Mr. Neison recorded the floor as very dark, the spots indistinct, not visible continuously; and Mr. Elger could just trace the "sector."

1870, Jan. 11, 7.20. Mr. Gledhill describes spot No. 1 as a large round crater, larger than Linné, quite bright and circular, a very fine easy object. At 7.30 the same evening, he says "Linné also is now seen as a crater, with some shadow within on the west." At 7.45 Mr. Gledhill writes: "Now the N.E. *inner* slopes of craters Nos. 1 and 3 glow in the bright sun, while the S.W. *inner* slopes are in shadow. It is the N.E. inner slope which so often, in bad definition, comes out as a bright disk or semidisk."

1869, August 16. Mr. Pratt thus writes:—"Of these difficult objects [the spots], *seven* were seen many times during the hour; No. 1 often well defined as a crater, Nos. 3 and 4 as well-defined craters as No. 1, but accompanied with a nebulous light, perhaps caused by the companion spots to each, which, however, were never clearly defined owing to the minuteness of the objects and the short periods of definition clear enough. They both had a similar appearance."

1870, September 4. Mr. Neison records No. 4 as just observable, and 14 very faint.

Interval 48 to 60 hours.

1870, May 10. Mr. Gledhill records spots Nos. 1, 3, and 17 as elevated craters with little internal shadows. Mr. Elger records No. 5 as seen only by glimpses much fainter than 17; 16 and 14 easy.

1871, March 1. Mr. Gledhill records spot No. 1 as a crater brightest on the inner E. wall.

1870, August 6. Mr. Elger noticed the *west* portion of the floor of an even light colour. It is on this portion that the spots Nos. 13, 19, and 22, which have decreased of late in visibility, are situated. On the 24th of March, 1870, Mr. Gledhill observed the reverse, viz. the *west* part of the floor exhibited the darkest tint. It was, however, less in extent than the light portion given by Mr. Elger, and was seen under the opposite illumination. See intervals 108^h to 96^h, and 12^h to 0^h*.

1870, October 4. Mr. Gledhill records No. 1 as an elevated object. Mr. Elger found No. 14 more easy than 5 and 17; it was not seen by Gledhill. Nos. 3, 30, and 17 were seen as bright disks by Gledhill.

* These reversed tints are quite in accordance with the surface of the floor dipping on each side from the line of "fault" crossing Plato from N.W. to S.E.

Interval 60 to 72 hours.

1870, July 8. Mr. Gledhill records Nos. 1 and 17 as bright spots badly seen. Mr. Elger records No. 5 as seen only by glimpses, but brighter than No. 1.

1869, August 17. Mr. Pratt inserted the positions of the spots observed by him "by independent estimation," also "their relative positions *with respect to light streaks*" were very carefully determined as follows:—

No.
1. On the dark surface near the junction of two streaks.
3. In the middle of a light streak.
4. In the middle of a light streak (sector)*.
17. On the dark surface close to a light streak (W. edge of sector).
13 and 19. In the middle of a light streak.
14. Near the margin of a light streak.

Interval 72 to 84 hours.

1870, April 11. Mr. Elger records No. 5 nearly as bright as 17, which he regarded as fainter than at last lunation; 14 and 16 were easy, 24 and 25 seen by glimpses. Mr. Gledhill records Nos. 1, 3, 30, and 17 as bright circular disks. Mr. Pratt detected the six spots which he observed with difficulty.

1870, March 13. Mr. Gledhill writes: "Unless I am very much mistaken indeed, 34 was an easy object, *i. e.* No. 1 came out easily 'double;' also, as the E end of the floor slopes to the east, spots Nos. 6 and 7 may be seldom seen on this account (?)." To this I add: "This may be the case while the moon is passing from perigee to apogee." Mr. Gledhill says further: "No 3 (and 30) very easy, wide, double; 3 is the larger, both equally bright: 30 is not seen nearly so often as 3; when only one is seen it is 3."

1870, June 9. Mr. Elger recorded 5 as brighter than 17.

1870, February 11, 6.30. Mr. Gledhill found spots Nos. 1 and 17 as very sharp bright disks, but could not detect interior shadows; he describes Nos. 1, 17, and 3 as sparkling. Of No. 1, he says, it often comes out double; last year I often saw it thus. I am now almost sure I see a minute object close to the west of it (34).

Interval 84 to 96 hours.

1870, December 4. Mr. Elger writes:—"The marking connecting the middle and east arm of trident, which was, I believe, first seen by Mr. Pratt last spring, I found a very easy object, fully as bright as the brightest portions of the 'trident;' it follows the curvature of the south border, and crossing the last arm of the trident, terminates about halfway between the latter and the west limit of the 'sector.' During the May and June lunations, I had faint glimpses of it; but it was then a very much more difficult object than it is now."

The apparition of this streak appears in some way to be connected with spot No. 5, the variations in visibility of which are considerable. As, from the discussion of visibility, the connexion of these variations with illuminating, visual or atmospheric (terrestrial), changes appears to be untenable, it may be suggested that, if the first maximum, Aug.–Sept. 1869, resulted from increased activity, ejecta may have been thrown out and produced the faint streak which was seen on the west of No. 5 by *two* observers. At or about the second epoch of increased activity, a larger quantity of ejecta

* Mr. Gledhill has frequently observed spot No. 4 at the angle formed by the converging sides of the "sector."

may have been thrown out, producing a brighter streak, extending eastward as well as westward. The most interesting circumstance connected with this streak is its conformity in direction to that of the south border, as if some peculiarity of the surface existed in the neighbourhood of No. 5, of a depressed character, which received the outflow or outthrow of the ejecta. Another noteworthy circumstance is, that this streak was not recorded earlier than May 13, 1870.

1870, September 6. Mr. Gledhill records Nos. 1, 3, 17, and 30 as bright disks, also that definition was good, and that the streaks and spots seemed to stand out in relief.

1869, November 15. Mr. Gledhill writes:—"The spots Nos. 1, 17, and 3 do not appear as a mere white *spot* on the floor of Plato would do. There is a sharpness and clearness of contour and a brightness (uniform) of surface which could only belong to a crater or peak. I have often been struck with this. This remark applies to them whenever they are well seen. I can only liken them to the small round disks of bright stars seen in the transit-instrument. Spot No. 4 never looks like Nos. 1, 17, or 3." To this I append the following query:—Do the clearness and sharpness of the contour of spots Nos. 1, 17, and 3 result from seeing the shadowless interiors of the craterlets? If so, on what agency does the appearance of the *mere* white spots depend? Do Nos. 1, 17, and 3 vary in this respect with good states of our atmosphere? Mr. Pratt records a spot new to him on the N.W. of 3, about half as far from 3 as is 4 on the opposite side, and aligning with 3 and 4; he speaks of it as exceedingly small. I have numbered it 29. He also observed spot No. 8, which he describes as fainter than 29, and situated about one third the distance from 3 towards 4. On this evening Mr. Pratt very carefully scrutinized No. 3 and its immediate neighbourhood; the following are his notes transmitted to me:—"*First.* The second spot, which I have always observed with 3 (and which I learn from Mr. Birt I have always placed in the same relative position as has Mr. Dawes, who discovered it, and of whose alignment I was before quite unaware), is exceedingly close to 3 on the N.E. I estimate the distance at 2″, and its position with respect to 1 was very carefully judged to be 145° to 150°, reckoning from S. round by E., which I afterwards found by comparison to be about the angle represented in my former sketches. *Second.* A third spot, S.E. of 3, and twice as far from it as Mr. Dawes's, was observed. Its relative size was judged to be one fourth, while that of the second spot was one third of 3. The direction was from 3 towards 4." [This spot I take to be 8.—W. R. B.]. "Another peculiarity in 3 was, that it was *just included* by the light streak, but still quite on its edge, as was also its smallest companion. I now determined very carefully *the colour of the immediate localities of all spots visible.* After independently noting it for each spot, I found on summing up that the whole were upon the light streaks, with the exception of No. 1, around and towards which the light streak was softly shaded off."

1870, July 9. Mr. Whitley glimpsed spot No. 17 with difficulty.

Interval 96 to 108 hours.

1870, April 12. Mr. Gledhill records Nos. 1, 3, and 30 as bright circular disks, 17 as a bright disk, also 6, but seen only once or twice. Mr. Pratt records No. 1 as very dense and bright, 3 and 4 as hazy, and 16 and 22 difficult.

1870, May 12. Mr. Gledhill records Nos. 1, 3, and 17 as fine bright disks, No. 4 a spot, but seldom seen. Marking α, Mr. Gledhill records as the brightest, and Mr. Elger mentions the part east of No. 16 as very bright

and well defined; this, as well as the remarks of Mr. Elger on May 9, may tend to throw some light on the decreased visibility of Nos. 13 and 19 (see Interval 24 to 36 hours). On this evening Mr. Whitley observed and described the markings, giving a sketch of the same. Mr. Elger's sketch of the north part of Plato and Mr. Whitley's are not in accordance. The time at which Mr. Whitley made his observations is not mentioned; Mr. Elger's 8.45 to 11.

1870, March 14. Mr. Elger writes: "The markings were not well seen; the eastern arm of the 'trident' was the brightest, and could be traced from the south rim to No. 1, passing to the west of No. 5: the marking γ was very plain, the rest of the markings were faint and difficult to make out." In contrast with this indistinctness on Plato, Mr. Elger says, "[In spite of the haziness of the sky, the markings and minute details of the *Mare Imbrium* were seen with unusual distinctness]." In the 'English Mechanic,' No. 312, March 17, 1871, p. 602, article "Mars," by F.R.A.S., the author speaks of the indistinctness and partial dimming on the surface of the planet, accompanied by the presence of dark lines in its spectrum, coincident with those referable by Father Secchi to the vapour of water. The indistinctness and dimming of detail are alike distinguishable on Mars and the Moon; and in addition we have on the Moon a number of spots becoming vividly bright with a high sun. From Dr. Huggins's observations, the spectral lines of the vapour of water are absent in the lunar spectrum.

1870, June 10. Mr. Elger recorded No. 17 decidedly brighter than No. 5 and equal to No. 3; 14 only glimpsed once or twice; 16 and 25 frequently seen.

1869, December 15. This evening Mr. Elger discovered spot No. 32. He described it as N.E. of spot No. 3, nearly aligning with 17 and 4, and situated on a brush of light (Gledhill's streak β), extending from No. 3 to the N.E. rim of Plato.

1871, March 3. Mr. Pratt observed 16 spots, viz. 1, 3, 4, 5, 14, 17, 21, 20, 23, 29, 0, 18, 13, 19, 7, 6, arranged according to relative brightness. Of these Mr. Pratt speaks of Nos. 20 and 21 as being far above their usual brightness. Situated as they are near the north border, the Moon going north in latitude, they were not in the most favourable position for observation; their great brightness is therefore remarkable, and connected with this is an increase of brightness in the streak α. The new streak between Nos. 5 and 17 Mr. Pratt saw with ease, joining the east arm of the "trident" with the "sector" from closely south of 17 to opposite 5.

1870, October 6. Mr. Gledhill records Nos. 1, 17, and 30 as fine bright disks; Nos. 5 and 6 equal. Mr. Elger observed Nos. 14 and 16, not seen by Mr. Gledhill; 14 was equal to 5.

Interval 108 to 120 hours.

1870, September 7. Mr. Gledhill records Nos. 1 and 3 as fine sparkling disks, and 4 as a hazy spot. Mr. Neison records Nos. 1, 3, 4, and 5 pretty distinctly visible; 17 brilliant but not well defined; 14 and 16 faint and very faint respectively.

1869, November 16. Mr. Gledhill says, "I never saw the floor so bright. The spots 1, 17, 9, 3, and 30 appeared just like small stars in the transit-instrument on a windy night." At 10, 11, and 12 hours Mr. Gledhill remarked that spots Nos. 3, 1, 9, and 17 formed a sparkling curve, and were fine easy objects, seen at a glance at any moment; he says they were very striking. On the contrary, he speaks of spots 23, 16, 19, 13, and 14 as very difficult objects; none were ever easy objects. Of 9 and 11 he says, "I never saw them so easily and well as to-night." The following notes are

important:—"Nos. 1, 3, and especially 17 (which surpasses all in sharpness, and perhaps in brightness *sometimes*) are fine easy objects, with moderate altitudes. Now Linné *never* appears like these except when near the evening terminator. As to γ Posidonius I never see it sharp and crater-like (white and bright) when the sun is up. I could not see it at all the other day when the morning terminator was a degree or two from it." Of *white spots* Mr. Gledhill remarks: "I called some spots *mere* white spots, because I have never seen them otherwise; by-and-by I may catch them near the terminator, and have reason to change the term. I fancy that when the terminator is a morning one the effect on objects differs from that given by the evening terminator."

Interval 120 to 132 hours.

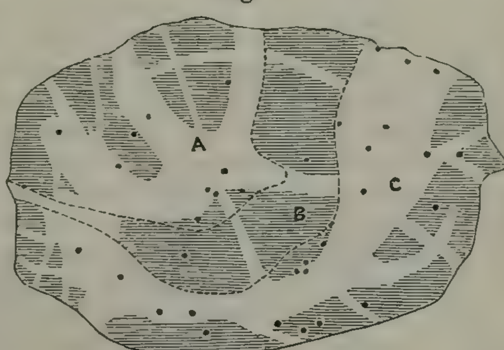
1871, March 4. Mr. Neison saw spot No. 14 very indistinct, and barely brighter than a longitudinal steak running in a direction from No. 13 to past No. 14, which was then situated upon it. It appeared to have its origin at the point of convergence of Gledhill's θ and δ. On the same evening, Mr. Gledhill recorded θ but not δ. On March 4, Mr. Neison saw No. 16 (once only) as a peculiar light-marked spot on a patch of broken light trending westward. Mr. Neison also recorded parts of the N.W. and S.E. portions of the floor indistinct from broken light and light streaks.

1870, June 11. Mr. Elger recorded spots Nos. 5 and 16 as seen only by glimpses.

Interval 132 to 144 hours.

1870, April 14. Mr. Gledhill records Nos. 1, 3, 4, 17, 9, 11, and 30 as bright round disks. Mr. Elger writes, under date of April 26, 1870, relative to his observations of April 14, as follows:—"That the visibility of the spots is connected with the position and brightness of the markings (as you suggest) is, I think, most probable: it is clear that the spots at present known are mainly confined to the districts occupied by the markings, and that the floor of *Plato* is divided by the latter into three nearly equal areas, A, B, C, as on sketch. Areas A and C are covered with markings, but area B is devoid of them. If we compare the number of spots in area B with the number of spots in areas A and C, we shall find that there are only *two* spots (23 and 11) in area B, while in area A there are *ten*, and in area C no less than *twenty-three*. It is true that small portions of the areas A and C are without markings; but the spots within those areas are, without an exception, situated either *upon* the light streaks or close to their borders. These facts seem to me very suggestive, and point to an intimate relation between the spots and markings. As observations accumulate, your present belief in a connexion between the phenomena will, I think, be placed beyond doubt." In connexion with the above, the following quotation from a letter by Mr. Pratt, dated 1870, April 22, is interesting:—"Very curious the difficulty there is in observing such delicate detail; possibly instruments and eyes will show differently, independently of the mental bias and accumulation of pre-

Fig. 7.



vious impressions; and I rather fear that telescopes much larger than my own cannot help us out of the difficulty."

The difficulty to which Mr. Pratt alludes is particularly felt with regard to that indispensable method of determining positions "measurement." Mr. Gledhill has executed some measures of the positions of the principal spots and the extremities of the light markings, and Mr. Pratt has aligned several of the spots with objects on the border; but so exceedingly delicate are the details, and so seldom is the state of the atmosphere sufficiently translucent and free from agitation, that to obtain an approximate plan of the spots and markings from measurement is necessarily a work of time. Pending this, in the above sketch both spots and markings have been inserted, partly on alignment and partly by estimation. The two light regions are well sprinkled with spots, as pointed out by Mr. Elger; and it is not a little interesting to notice that the nearly spotless area coincides with the region between the "trident" and the "sector," with its prolongation to "Webb's Elbow" near the N.W. border. In the absence of more accurate detail, which is likely to be obtained from Mr. Gledhill's measurements, the sketch (fig. 7) will serve as a guide for ascertaining if the spots and markings preserve their relative positions; and in this connexion the remarkable change of locality, if it be so, of spot No. 5 may be mentioned, Mr. Elger having seen and recorded on three occasions (1870, March 14, May 13, and October 10) its position on the eastern edge of the eastern arm of the "trident." It is possible there may be two neighbouring spots in this locality which have not yet been seen *together*. The importance of recording with every observation of spot No. 5 its position with regard to the eastern arm of the "trident" is obvious. The light streak supposed to be connected with No. 5 is too far south, or the spot is too far north, on the sketch.

1870, May 13. *Vide* "Indications of intermittent visibility" (p. 88).

1870, January 15. Mr. Gledhill observed as many as 22 spots, the second greater number seen on any one occasion. *Vide* "Indications of intermittent visibility." Spots Nos. 1, 3, and 17 are described as very easy, large, bright, sharp objects; No. 4 as jumping into view and not steadily seen. No. 34 was discovered this evening; it has not been observed since March 13, 1870, when it was recorded as an easy object.

1869, August 20, 21, and 23. Mr. Gledhill gives three spots close to the N.W. border, which he has marked 13, 19, and 16. No. 16 being too far east for that spot, I have regarded it as 20; if, however, Mr. Gledhill really saw 16, its degree of visibility would be slightly increased. On August 23 Mr. Pratt gives 16 in its proper position, and he observed the same number of spots as Mr. Gledhill; but Mr. Gledhill saw No. 12 and 31, which Mr. Pratt did not see, Mr. Pratt recording Nos. 7 and 30, not seen by Mr. Gledhill.

1870, September 8. Mr. Neison records spot No. 4 as a flat indistinct spot; 17 sharp but bright, darkening on one side, and showing traces of a crater-formation.

Interval 144 to 156 hours.

1870, August 10. Mr. Neison records spot No. 3 as apparently *oval*; the longer axis of the ellipse is in the direction of No. 31.

1870, October 8. Mr. Elger mentions No. 14 as very easy, 16 easy, and 17 seen only occasionally.

Interval 156 to 168 hours.

1870, May 14. Mr. Elger recorded No. 16 easy; 5, 14, and 17 faint; 25 and 32 seen by glimpses. Mr. Gledhill records 1, 17, 3, and 6 as bright disks, 4 not well seen, and 5 as a bright spot.

1870, September 9. Mr. Elger recorded No. 5 faint, 17 especially faint, 14 and 22 glimpsed, and 14 difficult.

Interval 168 hours to Meridian Passage.

1870, June 13. Mr. Gledhill has this remark: "For some time I have thought that when power 115 was used, spot No. 4 was almost at any time to be seen, or at any rate a condensation of the 'sector' at its apex was seen. On applying 240, however, the appearance vanishes, and no condensation or spot is seen, or perhaps only sometimes and at intervals."

Interval Meridian Passage to 168 hours.

1870, July 13. Mr. Gledhill records No. 1 as very bright.

1870, September 10. Mr. Elger records Nos. 25 and 16 as easy, No. 14 as seen by glimpses.

Interval 168 to 156 hours.

1870, August 12. Mr. Neison records "a spot seen on the border of No. 3, very small and hardly visible except at intervals, but pretty bright on edge only of the light marking." Mr. Neison suspected it to be No. 31, which it undoubtedly is according to the position which he has accorded to it on the diagram. Mr. Neison was the only observer who detected No. 31 during this lunation, on the 10th and 11th of August, as an elongation of No. 3. Mr. Elger, Mr. Gledhill, and Mr. Pratt appear to have missed it. Query, was the group Nos. 3, 30, and 31 in greater activity about this time? Mr. Neison has this note, "3. Faint indications of its being a crater very distinct." Mr. Pratt records: "During the long period since I last saw the light streaks I have had little opportunity to study former sketches, and so was free in a measure of the bias of them. Yet on sketching those seen, the forms, positions, and directions coincide with former drawings, notably the *trident* α, β, η, l." Mr. Pratt also notices a remarkable increase in brightness of spot No. 22, so as to attract especial attention. Neither Messrs. Elger, Neison, Ormesher, nor Gledhill noticed this spot, although they were observing on the same evening as Mr. Pratt, who further remarks "that in moments of best definition the area comprised between Nos. 19, 1, and 4 was not nearly so well displayed as the rest of the floor, giving a strong impression of an obscuring medium located there." [This observation of the streak l, the existence of which has been questioned, is perfectly independent of any suspicion of its non-existence, as it occurred some months before the question was raised.]

1870, October 10. Mr. Elger found spot No. 5 on the E. edge of the E. arm of the "trident;" its position, as given by Mr. Pratt, is on the W. edge of the E. arm. He also found that Nos. 5 and 14 were far inferior to 17. Spot No. 25 was easy. Mr. Elger did not see spots Nos. 9, 11, 18, 23, nor 30 recorded by Mr. Gledhill, nor did Mr. Gledhill see No. 14. For a special note on the position of spot No. 5, which Mr. Elger also saw on the E. edge of the "trident" on May 13, 1870, see Interval 132 to 144 hours.

1870. On the 12th of August, and on September 7, 11, and 12, Mr. Neison made a series of observations with apertures varying from 4 to $5\frac{1}{4}$ inches, with differences of $\frac{1}{4}$ of an inch.

Inches	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$
Spots	4	4	5	5	6	7

The spots seen were Nos. 1, 3, 4, and 17 with 4 and $4\frac{1}{4}$ inch apertures, the same and No. 5 with $4\frac{1}{2}$ and $4\frac{3}{4}$; with 5 inches aperture spot No. 14 was detected and marked as faint, and with $5\frac{1}{4}$ inches No. 16 was discerned:

the last two, Nos. 14 and 16, were in all cases marked as "faint," sometimes extremely so.

These seven spots are precisely those which have the highest degrees of visibility for 18 lunations, as under:—

Spots	1	3	4	17	5	14	16
Visibility ..	1·000	·897	·887	·830	·510	·433	·294

From these observations, it appears that spots Nos. 1, 3, 4, and 17 may be detected with instruments between 4 and $4\frac{1}{4}$ inches of aperture, that spot No. 5 requires an extra half inch, or $4\frac{1}{2}$ to 5, and that 5 and $5\frac{1}{4}$ will bring out spots No. 14 (5 inches) and 16 ($5\frac{1}{4}$ inches).

Aperture, of course, is an important element of visibility; and as these spots are seen with apertures *under* six inches, as the observations increase, and the normal degrees of visibility become well determined, variations in the visibility of these spots may be detected with instruments of 6 inches aperture, provided the observations extend over a sufficiently long period.

Elements of Visibility.

Lunar.—Brightness and size of spots.

Terrestrial.—Clearness and steadiness of atmosphere.

Instrumental.—Goodness of figure of object-glass or mirror, and extent of aperture.

Physiological.—Keenness of eyesight.

Interval 156 to 144 hours.

1870, July 14. Mr. Gledhill records No. 1 as a fine, large, bright spot, No. 17 as a small bright spot, Nos. 3 and 30 as bright spots, and No. 5 a bright spot, seen now and then. Mr. Ingall records No. 1 as very plain and sharp, No. 4 as steadily seen, and Nos. 3, 31, 30 a misty spot, probably consisting of these three.

1869, August 23. Mr. Pratt records that "spots Nos. 1, 3, 4, 17, 6, and 14 were very bright compared with their usual appearance, and all easily seen. No. 4 was not well defined; there was a persistent oval light round it (N.W. and S.E), and I several times believed it to be double, but could not be positive it was so. So remarkably clear was the vision that several times as many as *four* or *five spots* were *held in view at once*, without looking directly for them, and two or three times as many as six were so seen, viz. Nos. 1, 3, 4, 17, 5, and 14; again, Nos. 1, 3, 4, 17, 6, and 5. Nos. 4, 7, 6, 17 were a group seen together, and Nos. 5, 14, 22, and 1 were a similar one; yet still so exceedingly delicate are the fainter spots and the fainter traces of light on the floor that it needs a most concentrated attention to see either. In looking for the faint spots the faint traces of light will escape notice; again, when looking for the latter, the former are most likely not to be seen. This exceeding delicacy too interposes a serious *difficulty in aligning* them with objects on or near the border: the eye cannot hold so wide a view and at the same time retain a sufficiently correct impression of objects at once so faint and small. These remarks do not apply to the easier spots and light streaks. Once, for a few minutes, a narrow, dark, straight line, like a pencil-mark, was visible from *m* towards *Rambleta* [*i. e.* from N.W. to S.E.], probably the crack Mr. Birt has discovered. It was not seen again this evening."

1870, September 11. Mr. Neison records No. 1 as very distinct, No. 3 as distinct and brilliant, Nos. 5 and 14 as faint, 5 as rather so.

Interval 144 to 132 hours.

1871, March 8. Mr. Ormesher records a spot near the S.W. border, which he queries "14, a long way off" from its position. Is it a spot not before recorded?

1870, August 13. Mr. Gledhill records spots Nos. 3 and 17 as fine bright disks, No. 1 as a fine, large, bright disk, and No. 4 as a nebulous object. Mr. Pratt remarks that "on this evening, *as well as in* 1870, *August* 12, the tint of the dark portions of the floor was much intensified close to the rim. It was the case *all round*, but especially so between b and ζ, between ϵ and ζ, and between β and η."

1869, December 20. Mr. Pratt places a spot nearly due north of No. 1 on the diagram of this evening, which he queries as 23. I query it as uncertain. Spots Nos. 1, 0, 23, and 16 very nearly align. The line passing through Nos. 1, 0, and 23 passes slightly west of No. 16. Mr. Pratt's spot is very decidedly east of this line. [1871, March 31. The spot registered by Mr. Pratt on Dec. 20, 1869, not having been reobserved, it is probable that it may have been, as Mr. Pratt queried, No. 23. I have now entered it as such.—W. R. B.]

Interval 132 to 120 hours.

1870, September 12. Mr. Neison records of No. 22, "a spot very faint, and difficult to make out in the midst of a patch of light."

Interval 108 to 96 hours.

1870, July 16. Mr. Gledhill records spot No. 1 as "a fine, large, bright disk; looks like an elevation;" also Nos. 3 and 17 as bright disks. I have made the following note on the Form:—"9 and 0. These do not appear in their precise localities, especially 0. It may be that the spot thus marked by Mr. Gledhill is a new one."

1870, December 12. Mr. Pratt writes: "A faint crepuscular kind of shade has crept over the western part of the floor, and is deepest near the western border; but the gradation is very delicate, 12 hours to 12 hours 40 minutes." [1870, March 24. Mr. Gledhill noticed a darker tint at the west part of the floor, and furnished a tinted sketch: see remarks under this date (p. 87); also Mr. Elger's observations of the same portion of the floor being light, under date 1870, August 6, interval 48 to 60 hours.]

1870, November 11. Mr. Gledhill records spots Nos. 1, 3, 30, and 17 as *bright spots.* On the 13 of September (same interval) he recorded them as "bright or fine *craters*;" with the exception of Mr. Neison's record on August 12 of No. 3 as a suspected crater (interval 168 to 156 hours), this interval (108 to 96 hours) is the earliest in the declining day that the four have been seen *as craters.* The terminator is recorded as west of Fracastorius.

1870, September 13. Mr. Gledhill records spots Nos. 1, 17, and 30 as bright or fine craters, and says of 17, "fine crater as 1 and 3;" but of 3 he says, "fine disk." I have marked 3 *as a crater*.

Interval 96 to 84 hours.

1870, August 15. Mr. Pratt records that the darker margins of the shaded parts of the floor are still visible as on the 12th and 13th August, but not in such striking contrast.

1870, October 13. Mr. Pratt records spot No. 1 as brilliant, the others dimmer than usual.

Interval 84 to 72 hours.

1869, August 26. Mr. Pratt remarked a decided difference in definition

in different parts of the floor, even in so contracted an area, the whole northern half being less well defined, the south-east part the *best* so by far. Traces of the line from *m* to Rambleta were caught, and the floor appeared *unlevel*, the central and south parts appearing highest, and the south-west part next so. This, Mr. Pratt says, requires confirmation.

1870, September 14. Mr. Gledhill records No. 3 as a fine wide double spot (*i. e.* 3 and 30). Mr. Neison (same day) remarks as follows of Nos. 1, 3, and 17, seen by Mr. Gledhill as craters: No. 1 not very distinct; No. 3 sharp and shaded, not very bright; No. 17 very distinct.

Interval 72 to 60 hours.

1870, August 16. Mr. Pratt observed 3 spots only this evening. On October 14 (same interval) 16 were observed, 9 by Mr. Gledhill and 7 by Mr. Pratt, in addition. They both record the definition of the border as "good;" Mr. Pratt says, "with interruptions." On August 16, Mr. Pratt records the definition of the border as "bad." The following remark of Mr. Pratt is interesting in connexion with this paucity of spots:—"The darker parts or shaded portions of the floor were just perceptible with attention. 'Tint of floor' medium, much paler than on the 13th inst."

Interval 48 to 36 hours.

1870, August 17. Mr. Gledhill records No. 1 as a fine, large, open crater, 3 and 30 as craters, 17 as a small crater, and 4 as a bright but not definite spot.

Interval 36 to 24 hours.

1870, March 23. Mr. Gledhill writes: "The shadow of the elevated object on the east border (the rock ζ), close to the N. of W. II $E^{\psi 2}$, was on the floor, and the adjacent floor to the N.W. was *very bright*, much brighter than α or the 'sector,' and it extended one third of the distance from the border to spot No. 4, as in sketch." Mr. Gledhill could not determine its form, but considered that it was the streak η intensified.

1870, July 19. Mr. Gledhill observed the four craters 1, 17, 3, 30 only; he described No. 1 as a large circular crater with raised walls, but not much brighter than the floor.

1869, August 28. Mr. Pratt writes: "The LEVEL of the floor was conspicuously *divided* by the line from *m* to *c*, the ground sloping east and west of this line, the eastern part being brighter than the part on its west, while the locality of spot No. 4 was judged to be the highest of the whole floor." In connexion with this remark of Mr. Pratt it may be well to notice that, combined with Mr. Elger's observations on 1870, Jan. 10, of a depression in the floor east of No. 1 (see Interval 12 to 24 hours), the two suggest that this depression does not extend so far as No. 4. Again, comparing this observation of the western part of the floor being darker than the eastern, which is in accordance with Mr. Gledhill's on March 24, 1870 (see Interval 12 to 0 hours), it would appear that Mr. Elger's observation of the bright western area on 1870, May 9 and 10 and August 6, was an *intensified* brightness of the ordinary brilliancy of the floor, sloping to the west. The Intervals 24 to 36 and 48 to 60 hours, the season spring, with the sun's altitude about 14°, seem to indicate that the increased brightness was quite independent of illuminating angle.

Speaking of the apparent changes observed, not only on Plato, but over a wider range, between August 16 and 28, 1869, Mr. Pratt says: "Thus, among apparent changes of a particular character, and restricted to certain

small localities, there does appear to have been a *wider* and *more general disturbance* in the brightness and definition of objects, all which disturbance appears to be confined to *the low-lying lands* of that part of the moon observed. Not that changes were not visible in high regions; but these are more easily referred to changes of illuminating and visual angle, while the *disturbances* above mentioned are not so easily accounted for, especially those changes in the visibility of the light-streaks on the floor and the striking differences of brightness of the spots."

1869, October 26. In connexion with Mr. Gledhill's return of this date I remark, "'Crater Row' being so well seen, and the *border of Plato so sharp and distinct*, it is remarkable that spots Nos. 5, 6, 7, 13, 14, and 16 should not have been well and easily seen, although it appears they were seen, also that spot No. 3 should have been seen *single*, and that only sometimes, when it was seen double the previous night."

1870, November 14. Mr. Gledhill observed Nos. 1, 3, 30, and 17 *as craters*, and says, "they look like bright elevated rings."

Interval 24 to 12 hours.

1870, March 23. See *ante*, Interval 36 to 24 hours.

1869, September 27. Mr. Gledhill recorded a broad band of brightness parallel to the north border, enclosing spots Nos. 13, 19, and 16; he does not say they were *seen* as well as the bright band. I have, however, recorded them as having been seen.

Interval 12 to 0 hours or sunset.

1870, November 15. The four craterlets Nos. 1, 3, 30, and 17 are described by Mr. Gledhill as elevated crater-cones.

1870, March 24. Mr. Gledhill writes:—"Terminator on N.E. end of Apennines; the eastern shadows lie on the floor. A line drawn along the west edge of the 'sector,' and produced to the north border, separates the bright east part of the floor from the darker west part; the inner slope of the west wall glows in sunlight, while the floor near it is the darkest portion of the crater [Plato]." See p. 95, line 9.

Additional Notes.

Differences of Visibility of neighbouring Objects.

1869, August 26, 11 hours 30 minutes. Definition frequently exceedingly good but disturbed, with much boiling at times. Mr. Pratt has furnished the following record:—

"There was a marked *difference* between the *M. Imbrium*, the *M. Serenitatis*, and the *M. Frigoris*, in respect of the visibility of minute objects on their surfaces. The *Mare Imbrium* was literally *covered* with small white *spots* and *streaks*. The three streaks from *Aristillus* to the south border of *Plato* were again traced. *Archimedes* had roughly four *light* streaks E. and W., and about nine or ten easily discerned white spots. *Beer* and *Mädler* and neighbourhood looked invitingly for a close study.

"The *Mare Serenitatis* was of a dull grey, with *few* white spots and comparatively few features visible. Of those visible all were *very indistinct*, EXCEPT THE MORE ELEVATED ONES; thus, of the small objects round *Linné*, most were invisible, a few indistinct, even I Eθ^1, I Eθ^2, I Eγ^3 [the three small craters N.W. of *Linné*] were almost obscured. *Linné* itself a cloudy white spot, with knot of light in centre, but not nearly so bright as when seen on the 23rd inst. *Posidonius* γ was brighter and *half* the size of Linné. *Bessel* was tolerably clear. About half the number of white spots S.E. of

Bessel were very indistinctly seen, the remainder invisible. *Posidonius*, just within the terminator, was fairly defined. *Sulpicius Gallus* and one or two near it on the pleateau were clear; so that the MORE AN OBJECT WAS RAISED above the *general level* of the Mare the clearer was its definition, while those *on the level of it* were more or less *obscured.*

"The *Mare Frigoris* was *very hazy indeed*; even close to the foot of the north slope of Plato objects could not be defined, while those raised a little above the *Mare* were remarkably well defined indeed. The whole northern slope of Plato appeared everywhere rugged and uneven."

Indications of intermittent Visibility and of possible volcanic Activity.

On the evening of the 13th of May, 1870, no less than *twenty-seven* spots were seen on the floor of Plato, 26 by Mr. Pratt, and an extra one by Mr. Elger. This extraordinary display occurred between 132 and 144 hours after the terminator had passed 4° E. long. It is, however, not a little remarkable that, on the same evening, Mr. Gledhill, at Halifax, observed *four* spots only. The great number seen by Mr. Pratt, as compared with the small number seen by Mr. Gledhill, is doubtless due to a fine state of the earth's atmosphere at Brighton.

With regard to the streaks seen by Mr. Pratt on the same evening he remarks—"I could not see the small streaks on the western part of the floor, and sometimes even my old 'trident' and the streak κ were so indistinct as to be difficult. What was the cause? Surely not the earth's atmosphere; for *at the same time* spots could be seen. Perhaps we shall discover that spots are raised at a higher level than light streaks, and thus visible when streaks are obscured."

This remark of Mr. Pratt's is important: certainly the state of the earth's atmosphere could not have affected the two classes of objects in different ways. If the intensity of the spots depended upon the purity of our atmosphere, one would think that the brightness of the streaks would also have been increased; but in Mr. Pratt's experience it was not so. Mr. Elger speaks of some as bright and others faint. Mr. Gledhill, with a bad atmosphere, speaks of them as *bright*; but he saw only *four* spots. Are the spots really brighter than the streaks? But, then, why do both vary in brightness?

Mr. Pratt having perused [carefully] the MS. has furnished me with the following remarks:—

"May it not be well to mention that, on the occasion referred to, 1870, May 13, I observed *fifteen streaks*, one of which was a new one. [This was the streak from spot No. 5 towards No. 14.] This number was much above the average, the curious fact being that although so many were perceptible *with attention*, yet the increase in their brightness was in a lower ratio than that of the spots. There are two possibilities which may affect the discrepancy [difference] between the notes of Mr. Gledhill and myself in relation to the streaks:—First, *the times at which we observed* may have been different. As for myself, I tested the chance of working with any thing like satisfaction once at least every half hour during the whole of the evening, and before I tried for the last time, at 11 hours, had been unable to perceive either one spot or streak. Secondly, *priority of observation* bestowed on objects of one class may detract from the estimated brilliancy of the other class. In my own case, immediately I went to the telescope, at 11 hours, I saw several spots conspicuously, and in consequence searched *for spots alone* for nearly an hour. A search for so long a time for one class possibly may, in a slight measure, reduce the sensibility of the eye for objects of the other class, whether spots or streaks."

The following extracts from Mr. Pratt's letter, dated 1870, May 19, are

interesting:—"Some spots having at different times been observed as craterlets, their character as volcanic is settled in my own mind. Whether all spots are analogous I should be glad to know; but on the supposition of such similarity existing, the suggestion naturally arises whether the light streaks be not scoriæ or lava, or a mixture of both, resulting from the action of the craterlets with which they seem to be connected."

A comparison of the curves for the 20 lunations, April 1869 to November 1870, is suggestive of the *craterlets* being a distinct class of objects. The phenomena characterizing the cratelets, as indicated by the curves, differ very materially from the phenomena manifested by the spots; for example, in the correspondence of the maxima at the time of the supposed outbreak of Aug.–Sept. 1869, we have an increase of visibility in spots, the behaviour of the craterlets being altogether different. Certain neighbouring spots, to which allusion has been made, declined greatly in visibility, and were very seldom seen during a period in which the craterlets were almost always visible; and in connexion with this it may be remembered that craterlets are characterized by high degrees of visibility, while of many spots which have large ranges the normal degrees of visibility are low.

That a connexion exists between the streaks and spots is, as Mr. Pratt remarks, "self-evident;" and Mr. Elger has shown that most of the spots occur on the streaks. Now as both spots and streaks vary in brilliancy and visibility, may not the steaks consist, as Mr. Pratt suggests, of ejecta from the volcanic orifices of the craterlets? The increased brightness of the streaks in the neighbourhood of the border has been frequently noticed, as well as the *unevenness* of the floor. It may be possible that newly ejected matter (especially if it be of the character of "broken glass," suggested, I believe, by Dr. Huggins as explanatory of the appearance of Linné) may reflect light more strongly, and thus contribute to the brighter appearance of the streaks about the time at which the craterlets manifest increased activity, and this may become so great as even to conceal the craterlets themselves. On the other hand, although we are perfectly ignorant of any meteorological or chemical action occurring at the surface of the moon, it may be permissible to suggest that, if such action be possible, the reflective power of the ejecta may become impaired, and the streaks in consequence rendered less bright.

It is exceedingly difficult to conceive that volcanic action can be in existence on the moon's surface without "vapour" of some kind escaping from the orifices. If this be the case, condensation must follow, and the orifice may be covered by the condensed vapour, the upper surface of which may strongly reflect the light and produce the appearance of a spot when not in a state of actual eruption; and this spot may be seen on a surface covered with ejecta, the reflective power of which has been impaired since it left the orifice.

One of the brightest portions of the floor of Plato is the S.E., which is characterized by the "sector" or "fan." On the 10th of January, 1870, Mr. Gledhill observed as many as *nine* crater-cones on the eastern part of the floor, viz. Nos. 1, 9, 11, 17, 4, 3, 30, 7, and 32. It is easily conceivable that ejecta from some of these may be the perennial source of the reflective power of the "sector."

"It is, as far as I can see," says Mr. Pratt, "not at all *proven* that it is impossible that they, the spots, may not be small acting volcanos at this present moment; and you will please credit me with having noted that, on the 13th of May, although the spots were very greatly in excess of their usual brightness, the relative brilliancy of the light streaks was not nearly

in the same proportion, indeed not so high as on some nights when fewer spots have been visible. The supposition of Schröter of an exceedingly low atmosphere, confined to the lower regions, seems to me especially consonant with the above observations, for the following among other reasons :—

"*A thin atmosphere*, the only possible detection of which is confined to the lower parts of the floor [that is within the mountainous enclosure of Plato], may obscure the streaks partially [to effect this there must be condensed material of some kind] without affecting the spots, which, if craterlets, are raised more or less above the level of the streaks [the low fogs, the upper surfaces of which are at a less elevation than ordinary buildings are high, may be cited as examples]; for such an atmosphere would probably be rendered more dense by and during the supposed activity in the spots, which on that night were unusually bright and, according to the hypothesis, in action. [It must not be forgotten that on comparing the observations of Mr. Pratt with those of Mr. Gledhill, the presumption is that the unusual number and brilliancy of the spots was simply the effect of a finer atmosphere at Brighton as compared with that at Halifax. The phenomenon which is at variance with this is the less brilliancy of the streaks as recorded by Mr. Pratt; still we have the bright streaks of Mr. Gledhill supporting the hypothesis of the effects of the earth's atmosphere.] Hence after a subsidence of the brightness of the spots and the restoration of the normal state of the atmosphere, we might expect to see the streaks come out more distinctly."

It will be remarked that, in my suggestions above, the increased brightness of the streaks is supposed to depend upon the craterlets actually ejecting material, while the increased brightness of the spots depends upon the escape of vapour. I have not quoted Mr. Pratt's remarks for the purpose of controverting them; they appear to me to be exceedingly valuable, and in the present state of selenological inquiry it is important to canvass every view that may be put forward. It is quite consonant with both our views that increased activity in a spot may, and doubtless does, manifest itself by increased brilliancy; and it is not unlikely that the formation of a spot in the way suggested over a volcanic orifice otherwise *invisible* may precede an actual eruption, contributing to an increased brilliancy of the streaks if they really result from volcanic ejecta.

On the agencies capable of affecting the visibility of objects on the moon Mr. Pratt remarks:—"To my own mind the only likely agencies that can exist in the moon capable of affecting the visibility of objects are the everywhere-denied lunar atmosphere and real volcanic activity; as far as I can learn, the observations of some favour the one agency, while other observations do the same for the other, at the same time that different observers alternately deny the possible existence of either. Surely they are very closely related. If volcanic activity be established, can it exist without an atmosphere? While if a low atmosphere be established, would not the stronger objection to present volcanic activity be removed? The hope that persistent and minute observation of a suitable region might produce a result sufficient either to weaken or strengthen the supposition has been at once the impetus and bond which has induced me to give a large share of attention to Plato. We may not have attained such a result even yet; but possibly continued application may be rewarded. I hope so. The close study of typical species is generally the best method of acquiring a good knowledge of genera."

Mr. Pratt further adds:—"The reverse of what I have here stated I have several times observed, viz. that the light streaks on those occasions were

much *brighter relatively to their best state* than were the spots, of which generally at those times few have been discernible."

1870, May 13. Mr. Pratt has not only specified the order of brightness as follows:—

Spots No.:	1.	4.	3.	5.	17.	14.	22.	6.	13.	16.
Visibility:	1·000	·892	·897	·510	·830	·433	·175	·222	·156	·294
Spots No.:	20.	23.	18.	19.	29.	0.	24.	21.	9.	10.
Visibility:	·046	·046	·072	·150	·036	·046	·057	·026	·222	·062
Spots No.:	2.	25.	30.	31.	12.	7.				
Visibility:	·046	·144	·139	·031	·031	·113				

which we can compare with the degree of visibility for the 18 lunations as given immediately under the number of each spot (from this comparison we see that the brightness on May 13 was not strictly accordant with the visibility), but he has described the character of visibility by the words easy, conspicuous, &c., thus forming with the spots *not seen* eight classes of objects, an analysis of which may be interesting.

Class I. contains one spot only, No. 1, deg. of vis. = 1·000.
Pratt. Exceedingly bright and dense.
Elger. Unusually bright.
Gledhill. Bright spot.

Class II. contains one spot only, No. 4, deg. of vis. = ·892.
Pratt. Bright but hazy.
Elger. No remark.
Gledhill. Spot.

Class III. contains one spot only, No. 3, deg. of vis. = ·897.
Pratt. Distinct; he inserts 5 between 3 and 17.
Elger. 3 and 17 nearly equal.
Gledhill. Bright spot.

Class IV. contains four spots, viz. Nos. 17, 5, 14, 22,—

No.	Pratt.	Elger.	Gledhill.	Vis.
17.	Conspicuous.	Nearly equal to 3.	Bright spot.	·830
5.	"	Very faint on *east* border of eastern arm of "trident."	Not seen.	·510
14.	"	Seen by glimpses.	"	·433
22.	"	Not seen.	"	·175

Mr. Pratt observed the three components of the group 3, 30, 31: he described 30 and 31 as steadily seen; they occur in Class VI. Mr. Pratt accorded to spot No. 22 a high degree of brightness on this evening, and described it as "conspicuous:" neither Mr. Elger nor Mr. Gledhill detected it; this doubtless depended upon the state of our own atmosphere. It may, however, be remarked that the spot was less visible on May 13, 1870, as compared with its visibility in August 1869, when it was seen by every observer.

The position of spot No. 5, as observed by Mr. Pratt on August 26, 1869, was on the *west* border of the eastern arm of the "trident." The spot No 5, discovered by Challis, and possessing a normal visibility of ·510, has been so frequently observed as almost to warrant its stability of position; and should its *relative* position, as regards the eastern arm of the trident, be found to vary, it will afford evidence of a probable variation in the position of the arm. Schröter's drawings of the *Mare Crisium* indicate similar movements of the streaks from Proclus over the *Mare*.

Class V. contains eight spots, viz. Nos. 16, 6, 13, 19, 18, 20, 23, 29.

No.	Pratt.	Elger.	Gledhill.	Vis.
16.	Easy.	Easy.	Not seen.	·294
6.	„	Not seen.	„	·222
13.	„	„	„	·156
19.	„	„	„	·150
18.	„	„	„	·072
20.	„	„	„	·046
23.	„	„	„	·046
29.	„	„	„	·036

Of the spots in this class, and which Mr. Pratt describes as easy, one only, No. 16, was seen by Mr. Elger. This spot has a higher degree of visibility than 22 in Class IV., "conspicuous;" and this is perhaps another indication that the visibility of No. 22 on May 13 did not wholly depend upon the state of the earth's atmosphere.

The normal degrees of visibility in this class range from ·294 to ·036, furnishing a strong indication that they were seen in consequence of a fine state of the earth's atmosphere.

Class VI. contains five spots, viz. Nos. 9, 30, 24, 31, 21.

No.	Pratt.	Elger.	Gledhill.	Vis.
9.	Minute.	Not seen.	Not seen.	·222
30.	Steadily.	„	„	·139
24.	„	Seen 3 or 4 times.	„	·057
31.	„	Not seen.	„	·031
21.	„	„	„	·026

The same remark may be applied to this class as to Class V., viz. that the spots were seen in consequence of a fine state of the earth's atmosphere. The two spots Nos. 9 and 30, with comparative high degrees of visibility, are very frequently seen by Mr. Gledhill, and doubtless were not seen by him in consequence of the bad state of the atmosphere at Halifax.

Class VII. contains six spots, viz. Nos. 25, 7, 10, 2, 0, 12.

No.	Pratt.	Elger.	Gledhill.	Vis.
25.	..	Frequently glimpsed.	Not seen.	·144
7.	..	Not seen.	„	·113
10.	..	„	„	·062
2.	Hazy.	„	„	·046
0.	..	„	„	·046
12.	..	„	„	·031

Spot No. 25, vis. ·144, is frequently seen by Mr. Elger.

In addition to the above, Mr. Elger frequently glimpsed No. 32. *The* WHOLE *of the above spots,* as well as the *streaks* recorded by Mr. Pratt, were observed *three separate times* at intervals of about twenty minutes. The majority was seen much oftener.

The following spots were not seen on the evening of May 13:—

Spot:	11.	34.	8.	15.	33.	27.	26.	28.	35.
Vis.:	·144	·026	·015	·015	·010	·010	·005	·005	·005

With the exception of spot No. 11, which is frequently seen by Mr. Gledhill, these spots were doubtless concealed by or, rather, required a still finer state of the atmosphere to bring them out. It is difficult to say why Mr. Pratt did not detect spot No. 11 when he saw thirteen spots with lower degrees of visibility. It is one of those spots to which special attention

should be directed. Of the remainder, three have been observed *once* only by Mr. Gledhill, viz. Nos. 26, 28, and 35; two have been observed *twice*, viz. Nos. 27 and 33; two *thrice*, both old spots, viz. 8 (Gruithuisen) and 15 (Dawes); and one, No. 34, *six* times between January 15 and March 13, 1870*.

In his letter dated 1870, May 19, Mr. Pratt says that "spot No. 8 could not be recovered even with the most minute attention." Of spot No. 1 he says, "it was brighter than I have seen it before, *quite round* and dense, much like the image of a star on a good night surrounded by the very least trace of a ring of light. [Neither] internal nor external shadows could be seen, although I constantly expected a slight glimpse."

Spot No. 22.

In reference to this spot Mr. Pratt writes, under date 1870 August 26, as follows:—

"Spot No. 22, according to my observations, has manifested a remarkable increase of brightness, and those parts of the shaded portions of the floor of Plato which are nearest to the rim have come out more conspicuously darker than the rest than I remember to have previously noted. The tint of the floor, too, has progressively paled. These three phenomena [the increased brightness of spot 22, the intensification of the darker parts of the floor near the rim, and the progressive paling of the floor] may possibly be connected by a common cause; for certainly in this lunation there is somewhat of a coincidence amongst them; for instance, spot 22 is intensely bright at the time the marginal portions of the shaded parts are most conspicuously dark, and these two, again, coincide with the time when the general tint of the floor is at its darkest. Again, after August 12 and 13, spot 22 decreased in *relative* intensity, although I am not ready to hazard the assertion that it had on August 16 positively declined to its usual intensity, as it was not seen. [It was on this evening that Mr. Pratt observed three spots only.] Two similar instances, I believe, I have noted before, when 22 manifested a singular brightness at *sunrise*. But the connexion between the visibility of the deeper-tinted margin and the general deepening of colour is perhaps more close still, as both certainly paled after August 13. The perplexity seems to be that the variation in intensity of the margin is *relative* in respect of the general colour; and if differences of angles of illumination and vision do affect the general tint, it might be supposed that they would in the same manner affect the margin and so produce no *relative* variation of intensity."

In connexion with the relative intensity of which Mr. Pratt speaks, the state of the border is somewhat important. August 12 and 13, when the marginal portions of the floor were intensified in colour, Mr. Pratt recorded of the border:—"Definition fair at times, with much tremor, wind N.E." This was on the 12th. On the 13th the record is: "Border, definition bad,

* The history of spot No. 34 is curious; the following are the only records which exist of it. The observations were all made by Mr. Gledhill with the Halifax 9½-inch equatorial in the Observatory of Edward Crossley, Esq.

1870, January 15, 10 to 13 hours. "I am continually thinking I see an object close to No. 1 and to the west of it."

February 11, 6.45. "No. 1 often comes out double; last year I often saw it thus. I am now almost quite sure I see a minute object close to the west of it."

February 12, 6.0. "Saw 9, 11, 30, and object close west of No. 1."

March 12, 6 to 8 hours. No. 34 mentioned as having been seen.

March 13, 6 to 12 hours. "Unless I am very much mistaken indeed 34 is an easy object, *i.e.* No. 1 comes out easily double."

There are no records after this date. Instruments less than 9-inches aperture are not likely to redetect it.

much boiling, wind N.E." On the 12th, definition fair, the floor was recorded as "very dark." On the 13th it was dark, but not so much so as on the 12th. On the 16th, as well as on the 15th, the definition of the border was "bad." These records clearly throw a doubt upon the supposition of the "paling" having resulted from some lunar action, inasmuch as when the deeper tint was observed the definition was "good," the "tremor" and "boiling" having a tendency to confuse the portions of the floor. On the other hand, spots have been much more numerous with bad definition than 3 as observed by Mr. Pratt on the 16th; and this would lead to the supposition that the *apparent* extinction of the spots with a pale floor was in some way differently connected than by a deteriorated state of the earth's atmosphere. I have often observed that the passage of a thin cloud over the moon has greatly contributed to intensify the tints of the darker portions of the surface; but in this case the intensification has been general and not partial, as it would be if dependent upon local lunar action.

Mr. Pratt records a case of *partial obscuration* which was well seen on August 13. "It appeared," says Mr. Pratt, "on this wise. A general view of the floor showed it much speckled and streaked in other parts; but over the area specified [Mr. Pratt has not mentioned the particular part of the floor; but from what follows I apprehend it must be in the neighbourhood of No. 3] there seemed an absence of markings; close attention, however, enabled some to be seen, but not nearly so richly as the remainder of the floor, and we know well enough that that particular area is not wanting in markings. The evening's view has just occurred to memory when I first discovered that spot 3 was a triple one, and had a remarkable view of its neighbourhood [Qy. Was this on May 13 ?], therefore exactly the reverse being the case. August 13 seems as conclusive a proof as one observer is likely to obtain in a year's work."

Of four observers on the same evening, two record No. 3, and the other two appear not to have seen it. Taking them in chronological order, Neison, 9.5 to 9.15, records it as distinct; Pratt, 10.30 to 12.30, did not observe it; Ormesher, 11.0 to 11.30, does not show it in his drawing; Gledhill, 14^h, records it as a bright disk: he also records 30. As these observations are not contemporaneous, with the exception of Ormesher's, having been made while Pratt was observing, it appears, from its absence in both *their* records, that from 10.30 to 12.30 it was really not visible; and this tends to support Mr. Pratt's idea that for the time it was hidden by something like an obscuring medium. What this could have been it is difficult to surmise. The remark, however, of Neison that 30 was not to be seen between 9.5 and 9.15 is interesting in connexion with Gledhill recording both spots at a later epoch, 14^h, and also detecting five not seen by Pratt, viz. 3, 30, 9, 11, 18. Neison suspected he saw 14, not recorded by Gledhill nor Pratt, but seen by Ormesher. Pratt saw 22, not seen by either of the others. The case of 14 is a little perplexing; it might, however, have been missed by Pratt on account of the *bad* definition. With regard to the greater number of spots seen by Gledhill, two circumstances may have contributed to this result, the larger aperture of Mr. Crossley's instrument and the epoch at which Mr. Gledhill observed. It may possibly be found that the greater number of spots recorded after the sun's meridian passage at Plato depend upon the steadiness and purity of the air mostly experienced after midnight.

Sunset and Sunrise on Plato.

Extracts from Mr. Pratt's notebook, 1870, Oct. 17, 11^h to 12^h. Defini-

tion fair, with boiling. * * Plato is a grand and striking sight. Tint of floor medium. More than half the floor in shadow. Terminator just including the W. rim. The rim of the crater on the N. exterior slope finely seen. In three parts the rim appeared *broken down to level of floor*—close to *m*, opposite to *c*, and nearly so at W. II $E^{\psi 2}$ [the breaks at *m* and opposite *c* are in the line of the well-known fault crossing Plato from N.W. to S.E.]. ζ was throwing a long spire of shadow the full length of the floor at 11^h 40^m. That part of the floor contiguous to the W. and S.W. rim was deeply shaded, with streaks of shade running towards the centre of the floor. Between the break near *c* and the shadow of ζ a straight shading as of a narrow valley was well seen. [These shadings appear to be roughly coincident with the dark spaces on the floor as seen under high illumination, the straight shading being, as Mr. Pratt suggests, between the "sector" and the E. arm of the "trident." Is there really a valley here running into the central depression between 1 and 4, seen by Mr. Elger in January, 1870, and observed much earlier by Schröter?] Between these shadings and the shadow of the E. rim were *three roundish lighter regions*, the higher parts of the floor giving the appearance of a strongly marked convexity."

"A strong suspicion arises that the apparently higher portions of the floor are the *light streaks* usually seen, and the highest parts are spots 1, 17 and 5." Mr. Pratt further suggests that the light streaks are coincident with formations analogous to "spurs" from the chief centres of the residual activity on the floor.

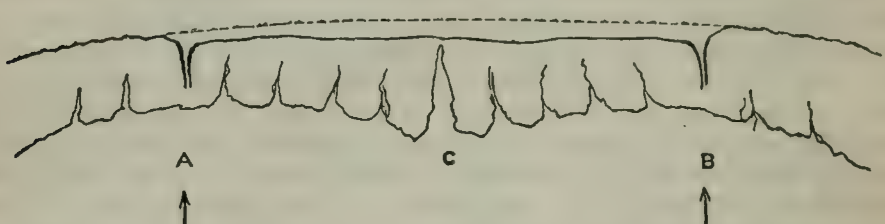
It is not a little remarkable that on the occasion of such a very favourable oblique illumination the craterlets 1 and 17 should not have been detected by Mr. Pratt; both have raised rims of the nature of true volcanic cones, and 1 has been seen, and I believe 17 also, with interior shadows and bright interiors facing the sun. Mr. Pratt does not appear to have seen even the remotest semblance of a shadow. The spots *properly so called* do not appear generally until the sun has attained an altitude of 20°. If craterlets are recorded as spots earlier, it is probably in consequence of bad definition confusing the crater-form appearance. Is it possible that on the two occasions mentioned by Mr. Pratt, Oct. 17 and Nov. 1, the craterlets 1, 17, 3, and 4 were by some means *concealed*? As regards Nov. 1, the observation of the crater-cones as the shadows gradually recede from E. to W. is very frequent; indeed the surface of Plato as it just emerges out of night appears to be in a very different state to what it is about mid-day; objects are much sharper, and it is difficult to conceive of any agency so affecting such visible objects as to render them invisible at a time when they are generally most conspicuous. So far as contemporaneous observations are capable of throwing light on this phenomenon, three spots only were recorded on the same evening; No. 1 by Mr. Elger, who noticed it from 9^h to 9^h 5^m, near the shadow of the summit of the middle peak of the W. wall, three hours later than Mr. Pratt's observation. Mr. Gledhill at 6^h, same as Mr. Pratt, says, "Moon so low and air so thick that very little light from moon can reach us;" he says also, "I see 3 as double elevated cones [*i.e.* 3 and 30]. No other objects can be seen." Mr. Neison, 5.10 to 8.15 [probably 8.10 to 8.15] succeeded in seeing 3 only, which he records as very faint. He does not give the state of the atmosphere as to definition; but from his remarking that "a deep cleft in west edge of wall was very distinctly seen," I should suppose that it was pretty good. Taking the four sets of observations it would appear that at sunrise on Plato Nov. 1, 1870, some agency was in operation capable of concealing the craterlets; and combining these observations with those of

Oct. 17, it would also appear that the same agency was in operation at the time of the previous sunset.

1870, Nov. 1, 6^h to $6^h\ 40^m$. "A grand view again. Definition fair at times. The margin of the eastern end of the floor very distinctly shaded, showing that end to be convex as well as the western. This shading did not conform to the general form of rim, but ran inwards (as shown in the sketch); and three places on the floor were much brighter than the rest, which was free from shading (their localities I have no doubt are those of spots 3, 4, and 17), while the next bright parts of the floor are suggestive of the light streaks; and the shading or lower part coinciding with the narrowing of the streak between 4 and 3 as seen under higher illumination in a measure supports the impression."

The dip of the floor towards the border, as mentioned by Mr. Pratt, is now well established by numerous observations, also the comparatively greater elevation in the neighbourhood of the fault crossing Plato from N.W. to S.E. These characteristics will probably afford some clue towards framing a theory of the formation of the plain and rampart. Starting with the now acknowledged principle that the moon manifests on a large scale the operation of volcanic forces, we may first inquire as to their *modus operandi* in the forms we observe. So far as we know, volcanos and earthquakes are closely connected, and there is great reason to believe that both are the results of *expansion* occasioned by the intumescence of material beneath the

Fig. 8.



crust or surface. It was, I believe, Scrope who first called attention to the effect of the expansion of an intumescent mass elevating the superincumbent material; and Hopkins, twenty-two years later, clearly showed that when the surface was elevated to the point at which the tension and cohesion just balanced each other, the slightest increase of tension ruptured the surface and produced fissures, which might be considerably augmented by earthquake-waves accompanied by the sudden subsidence of the tract between two principal lines of fissures. In applying this reasoning to the explanation of the formation of "Plato," the remarks of Scrope are so much to the point that a transcription of them is essential to the due apprehension of the forces concerned.

In chapter x. of his 'Considerations of Volcanos,' p. 205 (1825), Scrope, speaking of M. de Buch's opinion that the intumescence and rise of the basalt elevated the superincumbent strata, says: "I differ from him, inasmuch as I conceive the intumescence and rise of the basalt to be not the *cause* but the result of the elevation of the overlying strata.

"A general fact, noticed by M. de Buch himself, proves this most thoroughly, viz. that wherever the basalt appears, the strata are invariably found dipping *towards* it, which is wholly inexplicable under the idea that the basalt elevated them. . . . If, however, we suppose the expansion of the subterranean bed of crystalline rock to have taken place at a great depth, elevating the overlying strata irregularly along the line of various fissures,

as for example at A and B (fig. 8), it is clear such fissures will open *outwardly*; but in the interval of two such fissures, as at C, another must be found opening, on the contrary, *downwards*, that is, towards the confined and heated lava, which in consequence must intumesce and fill the space afforded to it, and perhaps force its way through some minor cleft upon the external surface of the elevated rocks."

Plato we know to be a large cavity in an elevated region, between the Mare Imbrium and the Mare Frigoris, connected with the mountain-studded region of the Alps on the west, and descending with a precipitous slope towards the east. The whole of the surface around Plato is exceedingly rugged, containing at least the remains of three craters of more ancient date. It is the floor of Plato only that presents any appearance of a recent character; and even this when viewed by very oblique light is far from being level. The sketch (fig. 8) to which reference has already been made is intended to convey some idea of the successive steps by which it is probable that Plato has arrived at its present form. It is roughly drawn to scale, which is somewhat too small, and, consequently, the height of the rim rather exaggerated; the extent being 316,800 English feet, the height, under 4000 feet (*i. e.* of the rim exclusive of the four pinnacles), will be nearly $\frac{1}{80}$th part. The letters A and B are placed over the supposed foci of expansion, the arrows indicating the direction of the elevating movements, the dotted line showing the extreme height to which the surface could be raised without fracture. Over A and B, and above C, are placed the three main fissures resulting from the increased tension and the general breaking up of the elevated mass, and which might have been accompanied with an almost immediate *subsidence*, as suggested by Hopkins, Report Brit. Assoc. 1847, p. 64, in the following passage:—"If the intumescence of the subjacent fluid, and consequently its supporting power, were immediately afterwards diminished by the escape of elastic vapours, there would be an immediate subsidence." Such a subsidence, or rather a succession of subsidences, would fully account for the formation of the floors of most craters; and the upwelling of lava from numerous small orifices would tend to produce such a floor as we observe on Plato. The section presents all the characteristics of the walled plain under consideration, the dip towards the border being strongly indicative of the main line of fissure opening outwardly at the foot of the rampart. It may be well to mention that no new principle is introduced in this explanation, which is based upon the views of two leading geologists, after comparing them with phenomena that have been assiduously and repeatedly observed.

Second Provisional Report on the Thermal Conductivity of Metals. *By* Prof. Tait.

Since the date of the former Report the Committee have obtained a splendid set of Kew standard thermometers. With these, complete sets of observations, at very different temperatures, have been made on iron, two specimens of copper, lead, german silver, and gas-coke. As great difficulty was found in keeping the source of heat at a constant high temperature in the statical experiments, they were repeated from day to day till satisfactory results were obtained. But a simple and ingenious device of Dr. Crum Brown (consisting in making the descending counterpoise of a small gas-holder *nip* an india-rubber tube) supplied so very great an improvement in steadiness of temperature that it was considered advisable to repeat all the statical expe-

riments with this modification. This has accordingly been done, during the present summer, but it has not yet been possible to perform the large amount of calculation necessary to obtain final results. It may be stated, however, that the results as a whole will not differ very considerably from those formerly obtained, so far, at least, as can be judged from a comparison of the graphic representations of the experiments.

Report on the Rainfall of the British Isles, by a Committee, consisting of C. Brooke, *F.R.S.* (*Chairman*), J. Glaisher, *F.R.S.*, Prof. Phillips, *F.R.S.*, J. F. Bateman, *C.E.*, *F.R.S.*, R. W. Mylne, *C.E.*, *F.R.S.*, T. Hawksley, *C.E.*, Prof. J. C. Adams, *F.R.S.*, C. Tomlinson, *F.R.S.*, Prof. Sylvester, *F.R.S.*, Dr. Pole, *F.R.S.*, Rogers Field, *C.E.*, and G. J. Symons, *Secretary*.

Your Committee have much pleasure in reporting that the organization under their supervision is believed to be in a generally efficient state. With a staff of observers, numbering nearly two thousand, spread over the whole extent of the British Isles, there can, however, be no question that, to ensure perfect efficiency and uniformity of observation, a systematic inspection of stations is absolutely necessary. In a paper read before the Society of Arts in 1858, Mr. Bailey Denton appears to have considered that there should be one inspector to about each 200 stations; at that rate we ought to have ten. The Meteorological Committee of the Royal Society have made it a rule to have all their stations inspected each year. On the most moderate computation it is indisputable that at least one inspector of stations is required for our large body of observers, the whole of whose time should be devoted to travelling.

Ever since their appointment your Committee have felt and acted upon this conviction; but want of funds has prevented them from employing a regular inspector, and obliged them to rely solely upon the unpaid services of their Secretary. Even under these adverse conditions considerable progress has been made with the work, and upwards of 400 gauges had been visited and examined previous to the Liverpool Meeting. At that Meeting, however, the Association only granted half the sum for which we asked, and we have consequently (most reluctantly) been obliged to stop this important and useful work.

As an interim measure, and with a view to ascertaining in what districts inspection is most requisite, it has been suggested that a schedule of questions as to the positions of their rain-gauges should be sent to every observer. The Committee unanimously approved of the suggestion, and annex a copy of the Circular and Schedule they are about to issue.

British Association Rainfall Committee,
62 Camden Square, London, N.W.

Sir,—The above Committee feel that it is most important that precise information as to the position of all the rain-gauges in the British Isles should be promptly obtained. They are aware that under present circumstances it is impossible that each gauge should be personally inspected, and have therefore instructed me to ask you to fill up the accompanying form, which I shall be obliged by your returning as soon as possible.

As an indication of the kind of information which the Committee desire to collect, I have filled up one form for my own gauge; but there are of course many subjects not touched upon in the specimen which will be ac-

ceptable in others, such as distance from the sea and from lofty hills, as well as their direction, &c.

The Committee will also be glad of any suggestions as to the conduct of rainfall work, and of information respecting any stations or old observations not included in the list published by them in 1866, and of which I shall be happy to send you a copy if you have not already received one.

Yours very truly,
G. J. Symons, *Secretary*.

[Illustration of mode of filling up return.]

POSITION AND PARTICULARS OF THE RAIN-GAUGE

At [**Camden Square, London,**]
In the County of [**Middlesex.**]

Year in which observations were first made [**1858.**]
Hour of observation [**9 a.m.**] If entered against the day of observation, or the one preceding [**Preceding**].
Position [**In garden, 120 ft. by 24 ft.**]
Surrounding objects, their distances and heights:—

		Distance.	Height.
N.	[**Wall**	**17 ft.**	**5 ft.**]
N.E.	[**House**	**92 ft.**	**40 ft.**]
E.	[**Wall**	**15 ft.**	**5 ft.**]
S.E.	[**Wall**	**12 ft.**	**5 ft.**]
S.	[**Wall**	**16 ft.**	**5 ft.**]
S.W.	[**Summer House**	**24 ft.**	**7 ft.**]
W.	[**Raspberry-bushes**	**6 ft.**	**3 ft.**]
N.W.	[**Wall**	**12 ft.**	**5 ft.**]

Inclination of ground [**Quite level, but in N.E. rises 30 ft. in ¼ mile.**]
Height of Ground above sea-level [**111**] ft. as determined by [**Levelling from Ordnance Bench-mark**].
Height of top of gauge above ground [**0**] ft. [**6**] in.
Pattern of gauge. (If similar to any on plate, quote the number; if not, give sketch.) [**Similar to No. X., but the bent tube is made straight, and a jar inserted for the purpose of ensuring more accurate measurement.**]
Have the same gauge and measuring-glass been used throughout? [**No.**]
Has the gauge always been in the same position? [**No.**]
If not, state briefly { the previous position [**300 yards further west.**]
the reason for the alteration [**Growth of trees.**]
the supposed effect [**None perceptible.**]

Remarks.

[**Measuring-glass broken in 1861, and a new tested one obtained, the rainfall of each day until its arrival being bottled separately, and measured by the new glass.**] Signed, [**G. J. SYMONS.**]

Another branch of investigation which has been arrested by the same cause is the relative amount of rain falling in different months, or, as we have usually termed it, the "monthly percentage of mean annual rainfall." Several articles upon the subject have appeared in our previous Reports; and last year we pointed out that the observations for the decade 1860–69 offered data of completeness unparalleled, either in this or any other country, the

result of which we had hoped to have submitted to the present Meeting. Excepting in our own Reports, we are not aware that the seasonal distribution of rain in this country has received any attention, while on the Continent it has at all times been looked upon as almost equally important with the gross amount.

Although several short and interrupted sets of observations have been made in Northern Derbyshire, the rainfall of that hilly district has not hitherto been examined with the thoroughness which its importance deserves. We have in previous Reports urged the desirability of several additional stations being established; and as no one else undertook the work our Secretary did so, and by the assistance of the observer at Buxton, and Mr. Hazlewood, of Castleton, was enabled to commence several sets of rain-gauge observations in the district. Some others are still required, which, if our funds permit, we intend to add.

Pit-gauges.—In our last Report we drew attention to the fact that a gauge of which the orifice was horizontal, level with the ground, but in a small pit or excavation, had at Calne collected about 5 per cent. more than one of which the receiving surface was one foot above the ground; whence it followed that as a great many rain-gauges (the majority in fact) are placed with their apertures a foot above the surface, the records of all these gauges were below what they would have been if placed in pits as just described. We gave some reasons which appeared to us to prevent the general use of pit-gauges, and added the following concluding remark on page 176 :—

"This result appears so startling that further experiments will be conducted on the subject."

The funds at our disposal have not allowed us to do so; but fortunately the Rev. F. W. Stow, M.A., has tried one pair of gauges mounted in this manner at Hawsker, on the Yorkshire coast, a few miles south of Whitby. The following are the results during 1870:—

Table I.—Experiments with Pit-gauges.

Hawsker, 1870.				Brit.Assoc.Report, 1869–70.	
Months.	5-in. gauge at 1 foot.	5-in. gauge in pit.	Ratio.	Calne, 1866–7, mean ratio.	Difference.
January	1·610	1·770	110	113	− 3
February....	1·995	2·300	115	109	+ 6
March	1·052	1·293	123	107	+16
April	0·370	0·390	105	105	0
May........	....	....	....	....	....
June	2·650	2·705	102	102	0
July........	0·920	0·977	106	103	+ 3
August	1·887	1·908	101	103	− 2
September ..	0·845	0·934	110	103	+ 7
October	5·000	5·053	101	102	− 1
November ..	3·043	3·234	106	106	0
December ..	5·230	6·420	123	108	+15
Totals	24·602	26·984	....	....	....
Means	....	....	109·3	105·5	+ 3·8

Of course it was not to be expected that the results of a single year should agree exactly with the mean of two other years, still less when the size of gauge used was different, and the locality so opposite as the inland district of Calne and the rock-bound Yorkshire coast. We therefore look upon it as satisfactory that in only four months out of eleven do the ratios at Calne and Hawsker differ more than 3 per cent. In April, June, and November they are identical. The Calne results are thus strongly confirmed; and it may be considered as certain that pit-gauges always exceed those at one foot, although the precise amount of excess remains to be determined.

In our last Report we expressed the hope that we should this year be able to state the result of the discussion of all the rainfall registers which were absolutely continuous from January 1, 1860, to December 31, 1869. We have the pleasure of doing so in two respects, viz. (1) with reference to their bearing on the question of the existence or otherwise of secular variation of rainfall in the British Isles, and (2) as data indicative of the distribution of rain over the country.

The secular variation of rainfall, or the relative dryness and wetness of different years and groups of years, is one of the most important and difficult branches of rainfall work. It has been treated in our Reports for 1865, and very fully in that for 1866. In the latter we gave the calculations in detail, from which the values shown on the accompanying diagram were obtained. Referring to that Report for full explanation, we have only now to mention that the subsequent years 1866 to 1869 have been computed in the same manner and added to the diagram (fig. 1). We may also remark that various observations collected since its publication have confirmed the general accuracy of the curve quite as much as could have been anticipated. On the present occasion we do not intend to discuss the relative rainfall of different years, but the relation of the fall during the ten years 1860–69 to previous decades. For this purpose we have grouped the yearly values in decennial periods, similar to those adopted in our 1867 Report, whence we obtain the following result:—

Table II.—Ratio of Rainfall in each ten years since 1730 to the Mean of sixty Years, 1810–69.

Period.	Ratio.	Period.	Ratio.
1730–39	89·9	1800–09	88·2
1740–49	70·6	1810–19	98·6
1750–59	85·5	1820–29	103·2
1760–69	91·1	1830–39	101·4
1770–79	103·5	1840–49	102·6
1780–89	93·5	1850–59	95·2
1790–99	96·5	1860–69	101·5

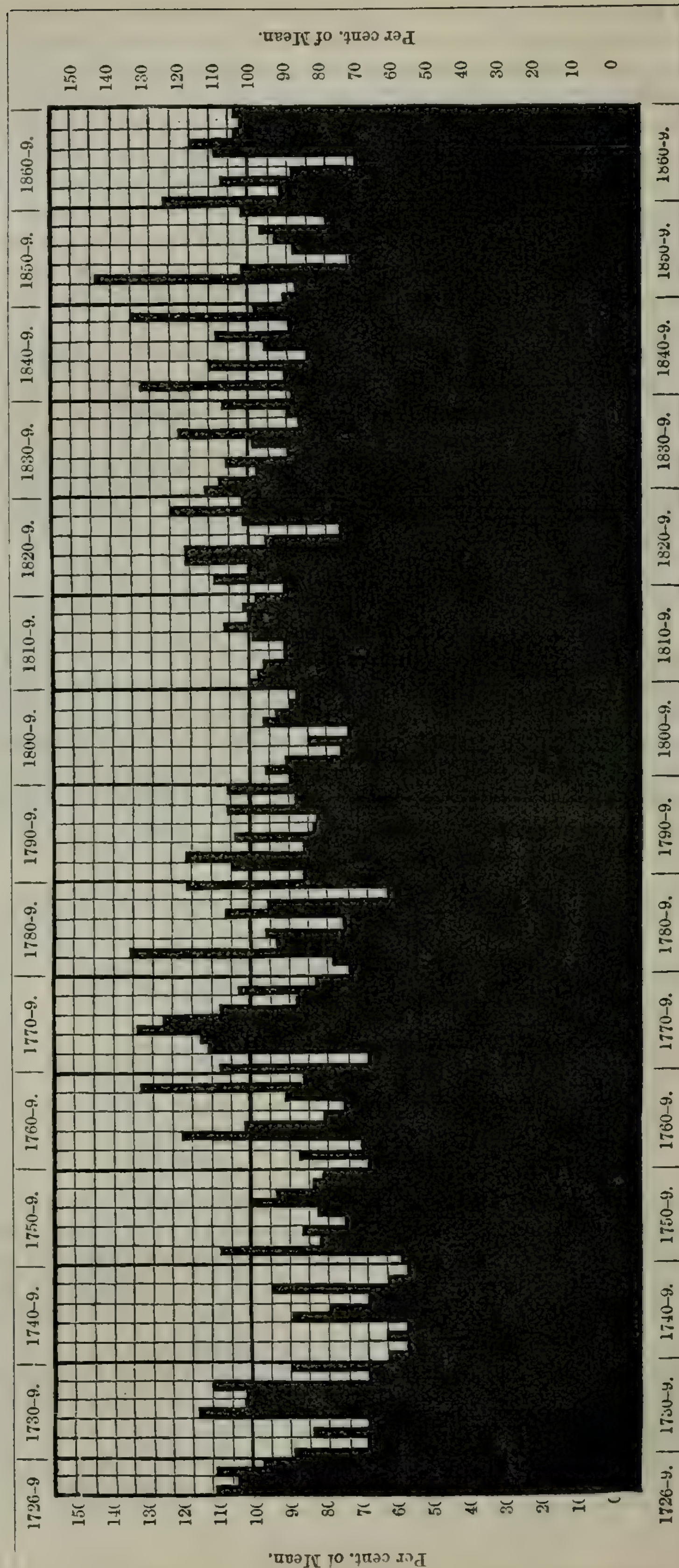
Having previously pointed out the peculiarities of the earlier portion of the curve, it is only necessary on the present occasion to call attention to the last forty years, whence it will be seen that, according to this mode of investigation (which is principally based on English returns), three out of the four decades had a rainfall nearly identical, and the other (1850–59) considerably below them, the deficiency being nearly 7 per cent.

This result is based on a combination of records, as fully explained in our 1866 Report. We proceed to examine how far it is corroborated by individual stations, but are at once confronted by the paucity of stations of which perfectly continuous records for even half a century exist. We therefore confine ourselves to the forty years, from 1830 to 1869, for which period we

Fig. 1.

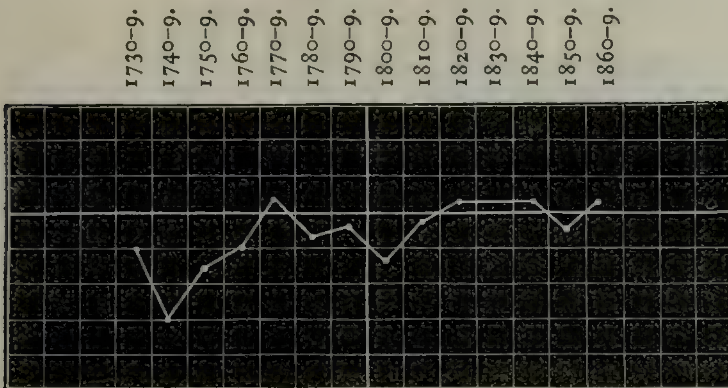
FLUCTUATIONS IN THE FALL OF RAIN,

FROM A.D. 1726 TO A.D. 1869.



have twelve perfect records at widely separated stations. The mean fall in each decade and in the whole period, and the ratio of each decade to the whole period at each station, is given in Table III.

Fig. 2.



From careful examination of Table III., it appears that the amount of rain which fell in the ten years 1830–39 was very similar to that which fell in the ten following years, the difference being a decrease, but scarcely one per cent. The investigation in our 1866 Report shows an increase of 1·2 per cent.; and examination of returns ceasing in 1850, and therefore not quoted in either Report, show several cases of absolute identity.

With one investigation leading to a decrease of 1 per cent., another to an increase of the same amount, and a third to identity, we are led to the conclusion that the two decades may be considered to show similar results. This is a much more important fact than it at first appears; and for this

Table III.—Comparison of the Rainfall in each Decade since 1829 with the Mean Rainfall of forty years, ending with 1869.

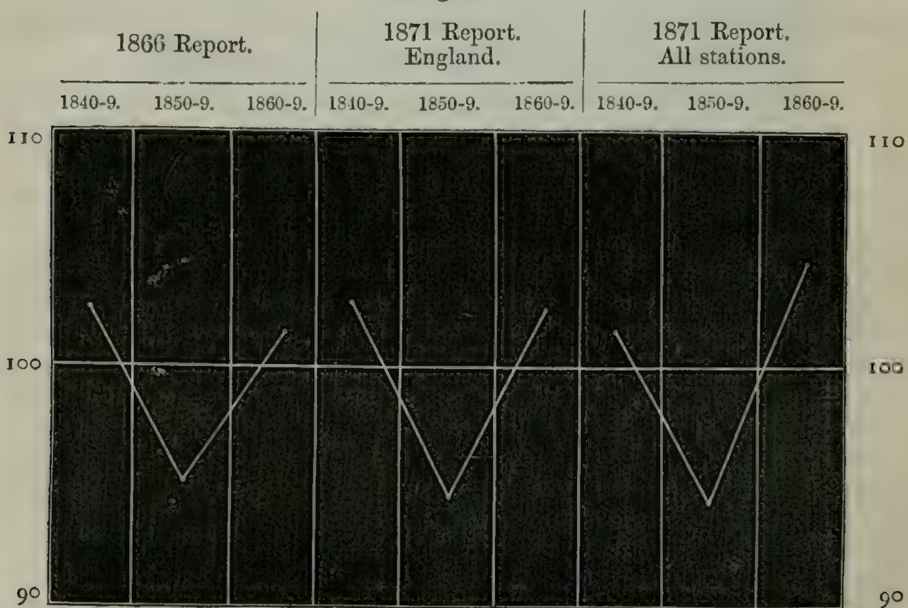
Station.	Mean Rainfall in each 10 years.				Mean Rainfall, 1830–69.
	1830–39.	1840–49.	1850–59.	1860–69.	
	in.	in.	in.	in.	in.
Epping	25·84	26·99	23·18	24·13	25·04
Exeter Institution	28·92	29·35	26·91	31·76	29·24
Tavistock	52·81	54·27	49·18	53·17	52·36
Halifax	34·51	31·88	30·71	33·31	32·60
Kendal	56·22	51·18	44·91	53·32	51·41
Point of Ayre....	28·26	28·20	29·01	30·61	29·02
Rhinns of Islay ..	34·07	33·79	30·58	33·43	32·97
Isle of May......	21·96	20·94	15·21	20·48	19·65
Buchanness......	26·40	26·84	23·40	25·59	25·56
Kinnairdhead	19·66	22·01	22·05	24·17	21·97
Island Glass	33·23	34·98	31·92	31·13	32·81
Start Point......	27·39	25·05	23·77	31·37	26·89
Means	32·44	32·12	29·24	32·71	31·63
Ratio of Means ..	102·6	101·6	92·5	103·4	

TABLE III. (*continued*).

Station.	Ratio of Rainfall in each 10 years' to 40 years' Mean.			
	1830–39.	1840–49.	1850–59.	1860–69.
Epping	103	108	93	96
Exeter Institution	99	100	92	109
Tavistock	101	104	94	101
Halifax	106	98	94	102
Kendal	109	100	87	104
Point of Ayre....	97	97	100	106
Rhinns of Islay ..	103	102	93	102
Isle of May	112	107	78	103
Buchanness......	103	105	92	100
Kinnairdhead	90	100	100	110
Island Glass	101	107	97	95
Start Point......	102	93	88	117
Mean Ratios....	102·2	101·8	92·3	103·7

reason: while there are only about a dozen registers complete for the four decades, there are thirty-eight which are complete for the last three decades. Now that we have found the relation between the first two decades, the returns for the thirty years are rendered almost as instructive as those for forty years.

Fig. 3.



We have therefore compiled Table IV., which differs from Table III. only in its being for thirty years instead of forty, and in giving observations from thirty-eight stations instead of twelve.

Table IV.—Comparison of the Rainfall in each Decade since 1839 with the mean Rainfall of thirty years ending 1869.

Division.	County.	Station.	Mean Rainfall in each 10 years.			Mean Rainfall.	Ratio of Rainfall in each decade to 30 years Mean.		
			1840–49.	1850–59.	1860–69.	1840–69.	1840–49.	1850–59.	1860–69.
			in.	in.	in.	in.			
II.	Sussex	Chichester Infirmary ...	29·10	26·67	29·03	28·27	103	94	103
„	„	„ (Chilgrove)...	33·41	32·23	33·22	32·95	101	98	101
III.	Herts	Hemel Hempstead	25·86	26·43	26·39	26·23	99	101	100
IV.	Essex	Epping.....................	26·99	23·18	24·13	24·77	109	94	97
„	Norfolk	Diss (Dickleburgh)......	25·05	22·31	22·22	23·19	108	96	96
V.	Wilts	Salisbury (Baverstock)	31·09	28·69	30·25	30·01	104	96	100
„	Devon	Tavistock (West St.) ...	54·27	49·18	53·17	52·21	104	94	102
„	„	Exeter Institution	29·35	26·91	31·76	29·34	100	92	108
„	„	Honiton (Broadhembury)	35·14	32·75	34·56	34·15	103	96	101
VI.	Worcester ...	Tenbury (Orleton)	28·41	28·82	30·90	29·38	97	98	105
VII.	Nottingham...	Welbeck	25·44	23·29	24·64	24·46	104	95	101
VIII.	Lancashire ...	Bolton (The Folds).....	46·46	44·01	48·98	46·48	100	95	105
IX.	Yorkshire ...	Redmires	40·75	37·86	39·68	39·43	103	96	101
„	„ ...	Halifax (Well Head) ...	31·88	30·71	33·31	31·97	100	96	104
„	„ ...	Settle	43·41	35·51	41·35	40·09	108	89	103
„	„ ...	York........................	25·42	22·02	24·48	23·97	106	92	102
X.	Durham	Bishopwearmouth	19·94	16·91	20·25	19·03	105	89	106
„	Westmoreland	Kendal......................	51·18	44·91	53·32	49·80	103	90	107
XI.	Isle of Man ...	Point of Ayre	28·20	29·01	30·61	29·27	96	99	105
XII.	Wigtown	Mull of Galloway, L.H.	20·67	22·52	27·66	23·62	88	95	117
XIII.	Haddington...	Haddington...............	23·77	24·35	25·63	24·58	97	99	104
„	Edinburgh ...	Inveresk	25·81	24·72	29·02	26·52	97	93	110
XV.	Bute	Pladda L.H.	40·02	35·23	40·14	38·46	104	92	104
„	Argyll	Mull of Cantire, L.H.	45·76	41·19	44·17	43·71	105	94	101
„	„	Rhinns of Islay, L.H.	33·79	30·58	33·43	32·60	104	94	102
XVI.	Fife	Isle of May, L.H.	20·94	15·21	20·48	18·88	111	81	108
„	Perth	Deanston	35·74	39·21	43·99	39·65	90	99	111
XVII.	Kincardine ...	Girdleness, L.H..........	23·14	19·71	22·72	21·86	106	90	104
„	Aberdeen	Buchanness, L.H.	26·84	23·40	25·59	25·28	106	93	101
„	„	Kinnairdhead, L.H. ...	22·01	22·05	24·17	22·74	97	97	106
XVIII.	Ross	Island Glass, L.H.......	34·98	31·92	31·13	32·68	107	98	95
„	„	Barrahead, L.H.	31·60	32·67	31·73	32·00	99	102	99
XIX.	Sutherland ...	Cape Wrath, L.H.	38·86	36·94	39·37	38·39	101	96	103
„	Caithness	Dunnethead, L.H.	27·39	22·09	25·40	24·96	110	88	102
„	Orkney.........	Start Point, L.H.	25·05	23·77	31·37	26·73	94	89	117
„	Shetland	Sumburghhead, L.H. ...	25·43	25·22	26·45	25·70	99	98	103
XXI.	Dublin	Black Rock	23·20	21·78	27·10	24·03	96	91	113
XXIII.	Antrim.........	Belfast Linen Hall	29·44	30·01	36·77	32·07	92	94	114

Abstract of Table IV.

England and Wales, 19 stations	33·23	30·60	33·28	32·37	102·8	94·7	102·5
Scotland, 17 stations..	29·52	27·69	30·73	29·31	100·9	94·0	105·1
Ireland, 2 stations	26·32	25·90	31·93	28·05	94·0	92·5	113·5
Mean of the above	29·69	28·06	31·98	29·91	99·2	93·7	107·0
Mean of 38 stations	31·21	29·05	32·07	30·78	101·5	94·3	104·2

From the above Table the remarkable similarity of the results obtained by the two dissimilar modes of investigation is rendered so obvious that it

is unnecessary to dwell further upon it. We now proceed to the second part of our investigation, namely, to consider the distribution of the rainfall of the last decade, during which we have nearly four hundred perfect sets of observations. As each set of observations comprises more than a thousand entries, and the following Table contains the result of nearly half a million observations, it is probable that it contains some slight percentage of error, but we have no suspicion of the existence of any which appreciably affect the results.

The head-lines of the following Table sufficiently explain its contents.

Table V.—Mean Rainfall at 325 Stations during the ten years 1860–69.

County.	Station.	Height of Rain-gauge. Above ground.		Height of Rain-gauge. Above sea.	Mean Annual Rainfall, 1860–69.
		ft.	in.	feet.	inches.
Division I.					
Middlesex	Camden Town............	0	6	100	25·681
Division II.					
Surrey........	Weybridge Heath	0	6	150	25·051
,, ...	Croydon (Tanfield Lodge) ..	0	8	155	26·333
,, ...	,, (Waldronhurst)....	35	0	237	24·388
,, ...	Wimbledon	3	0	160	23·476
,, ...	Kew Observatory	1	3	19	23·282
Kent	Hythe (Horton Park)......	1	4	350	32·677
,, ...	Tunbridge	1	0	71	28·258
,, ...	Maidstone (Linton Park) ..	0	6	296	27·559
,, ...	,, (Hunton Court)..	0	6	80	25·998
Sussex........	West Thorney [Emsworth]..	0	8	10?	26·875
,, ...	Chichester Museum	0	6	50	29·026
,, ...	,, (Shopwyke)	1	2	61	29·194
,, ...	,, (West Dean)	1	6	250	37·082
,, ...	,, (Chilgrove)......	0	6	284	33·224
,, ...	Arundel (Dale Park)	3	5	316	33·732
,, ...	Hastings (High Wickham)..	2	0	212	26·373
,, ...	Maresfield Rectory........	1	3	250	32·199
,, ...	,, (Forest Lodge) ..	1	2	259	31·479
Hampshire	Isle of Wight (Osborne) ..	0	8	172	30·725
,, ...	Fareham (North Brook)....	0	2	26?	33·906
,, ...	Petersfield (Liss)	0	7	....	38·033
,, ...	Selborne (The Wakes)	4	0	400	34·427
,, ...	Aldershot	3	0	325	27·036
Berkshire	Reading (Englefield)	1	0	190	25·726
,, ...	Long Wittenham	1	0	170	27·379
Division III.					
Herts	Bayfordbury	0	4	250	25·011
,, ...	St. Albans (Gorhambury) ..	2	9	....	27·849

TABLE V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground. ft.	in.	Above sea. feet.	Mean Annual Rainfall, 1860–69. inches.
DIVISION III. (*continued*).					
Herts	Hemel Hempstead (Nash Mills)	3	0	250	26·388
,,	Tring (Cowroast)	4	2	395	27·594
,,	Hitchin	1	4	238	23·922
,,	Royston	0	6	266	23·569
Bucks	High Wycomb	0	9	225	25·705
Oxford	Radcliffe Observatory	0	8	207	26·129
,,	Banbury (High Street)	7	0	350	26·222
Northampton	Althorp House	3	4	310	23·349
,,	Wellingborough	0	3	....	24·092
Hunts	Kimbolton (Hamerton)	5	4	170	23·132
Bedford	Cardington	0	0	106	22·487
,,	,,	3	6	109	21·760
,,	,,	36	0	142	18·170
Cambridge	Ely (Stretham)	4	9	....	20·609
,,	Wisbeach (Harecroft House)	0	8	11	24·037
DIVISION IV.					
Essex	Epping	6	0	360	24·132
,,	Witham (Dorward Hall)	1	6	20 ?	20·466
,,	Dunmow	0	0	234	22·750
,,	Braintree (Bocking)	3	6	200	23·984
,,	Saffron Walden (Ashdon)	1	0	300	23·056
Suffolk	Hadleigh (Aldham)	2	6	....	25·469
,,	Bury St. Ed. (Abbeygate)	35	0	240 ?	23·962
,,	,, (Westley)	1	0	216 ?	23·522
,,	,, (Barton Hall)	1	0	145 ?	23·680
,,	,, (Culford)	1	2	84 ?	24·835
Norfolk	Diss (Dickleburgh)	3	6	120	22·223
,,	Downham Market (Outwell)	4	0	16	22·637
,,	,, ,, (Fincham)	4	0	100	23·139
,,	Norwich Institution	30	0	53	22·169
,,	,, (Cossey)	1	0	....	24·035
,,	,, (Honingham Hall)	0	6	88	23·975
,,	Fakenham (Egmere)	4	8	150	25·097
,,	Holkham	0	0	39	23·875
,,	,,	4	0	43	23·232
,,	Hunstanton	3	8	60	19·559
DIVISION V.					
Wiltshire	Baverstock	3	0	300	30·247
,,	Salisbury Plain (Chiltern Ho.)	4	0	380 ?	29·279
,,	Swindon (Penhill)	0	10	....	28·592

Table V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground.		Height of Rain-gauge. Above sea.	Mean Annual Rainfall, 1860–69.
Division V. (*continued*).		ft.	in.	feet.	inches.
Dorset	Bridport	0	8	60	32·248
Devon	Plymouth (Saltram)	0	3	96	44·813
,, ...	,, (Ham)	3	0	94	42·888
,, ...	Plympton St Mary (Ridgeway)	0	6	116	48·646
,, ...	Tavistock (Library)	20	0	283	43·356
,, ...	,, (West Street)....	4	6	286	53·170
,, ...	Bovey Tracey	0	6	92	43·126
,, ...	Coryton Lew Down	6	0	445	45·941
,, ...	Exeter Institution	13	7	155	31·757
,, ...	Cullompton (Clyst Hydon)..	1	0	200	32·694
,, ...	,, (Bradninch) ..	1	6	234	38·060
,, ...	Honiton (Broadhembury) ..	1	6	400	34·562
,, ...	South Molton (Castle Hill)..	3	5	200	47·118
,, ...	Barnstaple	0	6	43	39·905
Cornwall	Helstone	5	0	116	37·872
,, ...	Penzance................	3	0	94	41·507
,, ...	Redruth (Tehidy Park)	0	6	160	41·229
,, ...	Truro (Royal Institution) ..	40	0	56	42·877
,, ...	,, (Penarth)..........	1	0	190	42·556
,, ...	Bodmin (Castle Street)	2	6	338	47·708
,, ...	,, (Warleggan)......	2	6	550	54·557
,, ...	Wadebridge (Treharrock Ho.)	2	9	303	39·301
Somerset	Langport (Long Sutton)....	0	10	50	28·574
,, ...	E. Harptree (Sherborne Res.)	1	0	338	42·097
Division VI.					
Gloucester	Bristol (Small Street)......	25	0	40	30·549
,, ...	,, (Phil. Inst.)	56	0	....	32·955
,, ...	Clifton (South Parade)	0	6	192	34·085
,, ...	Gloucester (Quedgeley)	0	10	50	27·421
,, ...	Cirencester (Further Barton)	1	2	420	32·612
Hereford	Ross (Archenfield)	1	0	250?	28·211
,, ...	,, (Rocklands)	1	10	150	33·591
,, ...	Leominster (West Lodge) ..	1	0	250	27·105
Shropshire	Burford [Tenbury]........	0	11	100?	26·744
,, ...	Ludlow (Knowbury)	0	4	1000?	28·530
,, ...	Shiffnal (Haughton Hall) ..	3	5	355	24·870
,, ...	Shrewsbury..............	4	4	192	19·499
,, ...	Oswestry (Hengoed)	6	0	470	35·647
Worcester	Northwick Park	1	6	....	28·017
,, ...	Worcester (Lark Hill)	1	0	137	28·039
,, ...	Tenbury (Orleton)	0	9	200 ?	30·900
Warwick	Birmingham (Edgbaston) ..	1	3	510	30·562

TABLE V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground.		Height of Rain-gauge. Above sea.	Mean Annual Rainfall, 1860–69.
		ft.	in.	feet.	inches.
DIVISION VII.					
Leicestershire ..	Wigston	0	6	220	25·165
,, ..	Thornton Reservoir	2	8	420	25·611
,, ..	Waltham Rectory	1	0	560	24·319
,, ..	Belvoir Castle............	1	0	237	24·476
Lincoln	Grantham	0	6	179	22·407
,, ...	Lincoln	3	6	26	20·870
,, ...	Market Rasen............	3	6	100	23·429
,, ...	Gainsborough	3	6	76	21·659
,, ...	Stockwith	3	6	21	21·347
,, ...	Brigg	3	6	16	24·118
,, ...	Grimsby	15	0	42	21·391
,, ...	Barnetby................	3	6	51	22·163
,, ...	Brigg (Appleby Vic.)......	0	9	60	24·097
,, ...	New Holland	3	6	18	22·665
Nottingham ..	Southwell	1	0	200?	20·844
,, ...	Welbeck Abbey	4	0	80	24·636
,, ...	Worksop	3	6	127	22·469
,, ...	Retford	3	6	52	22·743
Derby	Derby	6	0	180	26·807
,, ...	Chesterfield..............	3	6	248	26·930
,, ...	Kilnarsh (Norwood)	3	6	238	24·591
,, ...	Combs Moss	3	6	1669	49·620
,, ...	,, Reservoir	3	6	710	50·008
,, ...	Chapel-en-le-Frith	3	6	965	41·947
,, ...	Woodhead	3	6	878	52·188
DIVISION VIII.					
Cheshire	Bosley Minns	3	6	1210	32·849
,, ...	,, Reservoir	3	6	590	32·043
,, ...	Macclesfield..............	3	6	539	34·536
,, ...	,, (Park Green) ..	2	1	450	36·746
,, ...	Bollington (Spond's Hill) ..	3	6	1279	37·464
,, ...	Whaley	3	6	602	43·894
,, ...	Marple Aqueduct	3	6	321	34·810
,, ...	,, Top Lock	3	6	543	35·254
,, ...	Godley Reservoir	....		500	33·979
,, ...	Mottram (Matley's Field) ..	3	6	399	37·732
,, ...	Newton	3	6	396	31·633
,, ...	Arnfield Reservoir	....		575	37·232
,, ...	Rhodes Wood Reservoir....	1	0	520	46·323
,, ...	Woodhead ,, ...	0	10	680	51·828
Lancashire	Denton ,, ...	....		324	32·974
,, ...	Gorton ,, ...	....		263	33·712

TABLE V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground.		Height of Rain-gauge. Above sea.	Mean Annual Rainfall, 1860–69.
		ft.	in.	feet.	inches.
DIVISION VIII. (*continued*).					
Lancashire	Manchester (Old Trafford) ..	2	7	106	34·727
,, ...	,, (Ardwick)	3	0	154 ?	32·597
,, ...	,, (Piccadilly)	40	0	194	36·775
,, ...	Fairfield	6	0	312	40·898
,, ...	Oldham (Waterhouses)	3	6	345	36·133
,, ...	,, (Gas-works)	6	0	600	37·123
,, ...	,, (Strines Dale)	6	0	800	36·007
,, ...	Bolton (The Folds)	3	6	283	48·981
,, ...	,, (Belmont)	0	0	800	56·610
,, ...	,, (Heaton)	0	0	500	44·210
,, ...	Rochdale (Nagden Dane) ..	1	6	900	44·132
,, ...	Ormskirk (Rufford)	0	8	38	34·999
,, ...	Preston (Howick)	0	6	73	38·303
,, ...	Blackpool (South shore)	1	8	29	32·994
,, ...	Stonyhurst	0	8	376	48·560
,, ...	Clitheroe (Downham Hall) ..	1	6	464	44·786
,, ...	Lancaster (Caton)	1	6	120	43·944
,, ...	Cartmel (Holker)	4	8	155	45·625
DIVISION IX.					
Yorkshire, W. R.	Sheffield (Broomhall Park) ..	2	0	340	31·276
,,	Redmires	4	0	1100	39·684
,,	Sheffield Station	3	6	188	28·159
,,	Tickhill	2	0	61	23·990
,,	Dunford Bridge	3	6	954	56·177
,,	Saddleworth Station	5	0	640	41·968
,,	Standedge	2	0	1150	53·700
,,	Huddersfield (Longwood) ..	4	6	650	34·008
,,	,, (Rastrick)	1	3	410	32·121
,,	Halifax (Warley Moor)	....		1425	46·330
,,	,, (Well Head)	0	11	487	33·313
,,	,, (Midgeley Moor) ..	....		1350	50·000
,,	,, (Ovenden Moor) ..	....		1375	46·090
,,	Leeds (Leventhorpe Hall) ..	2	0	90	23·261
,,	,, (Holbeck)	32	0	127	22·853
,,	York (Bootham)	0	6	50	24·479
,,	Settle	40	0	498	41·349
,,	Arncliffe	2	9	750	60·075
,, E. R.	Hull (Beverley Road)	3	10	11	25·024
,, N. R.	Malton	1	0	75	27·455
,,	Richmond (Aske)	2	8	550	31·105

TABLE V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground.		Height of Rain-gauge. Above sea.	Mean Annual Rainfall, 1860–69.
		ft.	in.	feet.	inches.
DIVISION X.					
Durham	Bishopwearmouth	....		....	20·247
Northumberland	Allenheads	0	9	1369	51·160
,,	Shotley Hall	0	3	312	28·494
,,	Bywell..................	0	6	87	28·874
,,	Wylam Hall	0	4	96	26·900
,,	North Shields (Wallsend) ..	0	6	100	26·640
,,	,, (Rosella Place)	1	0	124	26·065
,,	Stamfordham	1	0	400	27·637
,,	Hexham (Parkend)	0	4	276	33·550
,,	Lilburn Tower	6	0	300	28·657
Cumberland ..	Seathwaite	1	0	422	154·046
,, ..	Ullswater (Watermillock) ..	3	6	720	59·910
,, ..	Bassenthwaite (Mirehouse)..	0	7	310	53·756
,, ..	Cockermouth (Whinfell Hall)	2	0	265	57·366
,, ..	Carlisle (Bunker's Hill)	6	0	184	27·616
Westmoreland..	Kendal (Kent Terrace)	4	6	146	53·322
,, ..	Windermere (The Howe) ..	1	2	470	87·923
,, ..	Appleby	1	0	442	35·994
DIVISION XI.	WALES AND THE ISLANDS.				
Glamorgan	Cardiff (Ely)	3	0	45	42·016
Cardigan	Lampeter	4	6	420	45·183
Brecknock	Hay (Pen-y-maes)	1	0	317	31·680
Radnor	Rhayader (Cefnfaes)	2	0	880	44·980
Flint	Hawarden [Chester]	0	7	270	26·443
,, ...	Holywell (Maes-y-dre)	5	0	400	24·430
Denbigh	Llandudno (Warwick House)	0	6	99	31·004
Isle of Man....	Point of Ayre	3	4	27 ?	30·609
Guernsey	....	12	0	204	37·177
Alderney......	Harbour Works	10	0	48	28·624
DIVISION XII.	SCOTLAND.				
Wigton	Mull of Galloway	....		....	27·656
,, ...	Stranraer (South Cairn)....	1	4	209	49·603
,, ...	Corsewall	....		....	37·027
Kirkcudbright..	Little Ross	3	3	130 ?	26·981
,, ..	Cargen [Dumfries]	0	4	80	44·372
Dumfries......	Dumfries (March Hill Cott.)	0	5	70	37·045
,, ...	Westerkirk (Carlesgill)	....		....	60·092
,, ...	Wanlockhead	0	4	1330	66·628
Roxburgh	Kelso (Springwood Park) ..	1	0	130	24·663

TABLE V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground.		Above sea.	Mean Annual Rainfall, 1860–69.
		ft.	in.	feet.	inches.
DIVISION XIII.					
Selkirk	Bowhill	11	0	537	33·033
Peebles	Penicuick (N. Esk Reservoir)	0	6	1150	38·014
Berwick	Lauder (Thirlestane Castle)...	0	3	558	29·977
,, ...	Dunse (Mungo's Walls)	0	6	267	28·494
Haddington....	Prestonkirk (Smeaton)	13	0	100	23·263
,, ...	Haddington (Millfield)	4	0	140	25·630
,, ...	East Linton	0	3	90	23·767
Edinburgh	Cobbinshaw Reservoir	0	7	863	37·450
,, ...	Inveresk	2	0	90	29·016
DIVISION XIV.					
Lanark	Hamilton (Auchinraith)....	4	9	150	31·951
,, ...	,, (Bothwell Castle)..	18	0	146	28·885
,, ...	Glasgow (Cessnock Park) ..	4	4	29	37·958
,, ...	,, (Observatory)	0	1	180	44·411
,, ...	Baillieston	0	3	230	46·471
,, ...	Shotts (Hillend House)	7	0	620	33·445
Ayr	Ayr (Auchendrane House)..	2	3	96	44·825
,, ...	Largs (Mansfield)	0	6	30	48·920
Renfrew	Gorbals, W. W. (Ryat Lynn)	0	5	310	47·801
,, ...	,, (Waulk Glen)	0	5	280	49·845
,, ...	,, (Middleton)...	0	5	550	56·682
,, ...	Mearns (Nether Place)	0	6	360	50·143
,, ...	Greenock (Hamilton Street)	0	6	50	66·156
DIVISION XV.					
Dumbarton	Loch Long (Arddaroch)	0	10	80	78·321
Stirling	Falkirk (Kerse)	1	0	....	32·960
,, ...	Stirling (Polmaise Gardens)	0	2	12	41·300
Bute	Pladda..................	3	3	55	40·141
Argyll	Castle Toward............	4	0	65	54·554
,, ...	Lochgilphead (Callton Môr)..	4	6	65	54·253
,, ...	Inverary Castle	0	1	30	67·370
,, ...	Appin (Airds)............	0	3	15	63·640
,, ...	Ardnamurchan	3	6	82?	45·594
,, ...	Cantire, Mull of	....		279?	44·166
,, ...	Campbeltown (Devaar)	3	4	75?	47·312
,, ...	Rhinns of Islay	3	0	74?	33·434
,, ...	Lismore (Mousedale)	3	4	37?	46·215
,, ...	Mull, Sound of	0	6	12?	72·159
,, ...	Tyree (Hynish)	....		....	79·992

TABLE V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground.		Height of Rain-gauge. Above sea.	Mean Annual Rainfall, 1860–69.
		ft.	in.	feet.	inches.
DIVISION XVI.					
Kinross	Lochleven Sluice..........	0	10	....	35·780
Fife..........	Balfour	0	6	127	28·589
,, ...	Leven (Nookton)	0	6	80	28·988
,, ...	Isle of May...............	2	2	182	20·482
Perth	Aberfoyle	0	6	60	61·820
,, ...	Dunblane (Kippenross)	0	4	100	36·165
,, ...	Deanston House	0	4	130	43·991
,, ...	Lanrick Castle............	0	0	....	48·805
,, ...	Bridge of Turk	0	6	270	61·890
,, ...	Auchterarder House	2	3	162	34·315
,, ...	,, (Trinity Gask)	0	1	133	35·324
,, ...	Loch Earnhead (Stronvar) ..	....		....	82·434
,, ...	Perth Academy	64	5	83	23·584
,, ...	Scone Palace	2	6	80	29·182
Forfar........	Barry	0	3	35	29·729
,, ...	Craigton	0	3	481	34·876
,, ...	Kettins	1	0	218	33·172
,, ...	Hill Head	0	3	570	35·187
,, ...	Arbroath................	2	0	60	29·050
DIVISION XVII.					
Kincardine	Brechin (The Burn)	0	6	235	34·910
,, ...	Girdleness	4	7	86	22·718
Aberdeen	Braemar	1	0	1114	33·404
,, ...	Aberdeen (Rose Street)	0	4	95	29·433
,, ...	Alford (Castle Newe)......	....		....	33·500
,, ...	Kinnaird Head	3	4	64	24·168
,, ...	Buchanness	....		....	25·588
Banff	Gordon Castle............	1	6	60	29·192
DIVISION XVIII.					
Ross & Cromarty	Isle of Lewis (Stornoway) ..	3	4	31?	31·792
,, ,,	,, (Bernera)	0	6	15	68·027
,, ,,	Cromarty...............	3	4	28	25·941
Inverness	Isle of Skye (Oronsay)	0	6	15?	72·359
,, ...	,, (Kyleakin)	0	2	3?	82·067
,, ...	,, (Raasay)......	1	4	80	77·120
,, ...	,, (Portree)......	1	8	80	104·261
,, ...	Barrahead	3	0	640?	31·726
,, ...	S. Uist (Ushenish)	0	4	157?	43·905
,, ...	Harris (Island Glass)......	3	4	50?	31·129
,, ...	Rona	0	6	20	39·470
,, ...	Culloden House	3	0	104	27·084

TABLE V. (*continued*).

County.	Station.	Height of Rain-gauge. Above ground.		Height of Rain-gauge. Above sea.	Mean Annual Rainfall, 1860–69.
		ft.	in.	feet.	inches.
DIVISION XIX.					
Sutherland	Golspie (Dunrobin Castle) ..	0	3	6	27·692
"	Cape Wrath..............	3	6	355 ?	39·371
Caithness......	Wick (Nosshead)	3	4	127 ?	24·699
"	Dunnethead	3	6	300 ?	25·401
"	Pentland Skerries	3	3	72 ?	28·763
Orkney	Hoy (Graemsay East)	3	4	27 ?	39·007
"	" (" West)	....		37 ?	32·693
"	Shapinsay (Balfour Castle)..	0	6	50	32·408
"	Pomona (Sandwick)	2	0	78	38·853
"	Sanda (Start Point)	0	6	29 ?	31·371
"	North Ronaldshay	3	4	21 ?	31·015
Shetland	Sumburghead	3	4	265 ?	26·454
"	Bressay Lighthouse	0	4	60	36·488
	IRELAND.				
DIVISION XX.					
Cork	Cork (Royal Institution) ..	50	0	70	34·771
"	Fermoy	....		....	37·207
Waterford	Waterford (Newtown)	4	0	60	40·669
Clare	Killaloe	5	0	123	47·654
DIVISION XXI.					
Queen's County..	Portarlington	1	2	240	36·857
King's County..	Tullamore	3	0	235	27·938
Wicklow	Bray (Fassaroe)	5	0	250	41·822
Dublin........	Black Rock (Rockville)	29	0	90	27·096
DIVISION XXII.					
Fermanagh	Enniskillen (Florence Court)	11	0	300	44·368
Armagh	Armagh Observatory	1	5	208	32·014
Antrim	Belfast (Queen's College) ..	7	4	68	34·225
"	" (Linen Hall)	4	0	12	36·767

Before accepting these decennial averages (1860–69) as data indicative of the distribution of rain over the country, we have to offer a few prefatory remarks. The difference between the amount collected by any two rain-gauges depends on at least four separate and distinct conditions, three of which must be ascertained and corrected for before the fourth can be accurately determined.

The conditions are:—(1) length of series of observations; (2) correction for secular change; (3) height of gauges above ground.

(1) Even if there were no other evidence in existence than the accompany-

ing diagram (fig. 1) of the fluctuations of rainfall, we feel that it would sufficiently prove the impossibility of determining accurately the rainfall at any place except by observations continued over a long series of years at that place, or by differentiation from some proximate long-continued series.

(2) It does not follow that simultaneous observations, even for ten years, giving for example a mean difference between two stations of five inches, prove that the rainfall at the one station is greater than the other by that amount, although if they are not very distant the one from the other it would probably be a safe assumption.

(3) Before mean results can be given with any pretensions to accuracy and finality, they must be corrected for the elevation of the rain-gauge above the ground.

The above remarks sufficiently show that the mere average of the fall of rain measured during ten or more years does not necessarily give the true mean rainfall at that place.

Let us take as an example the highest amount recorded in the Table (Seathwaite), which had during the ten years (1860–69) an average of 154 inches; many persons would say at once that that was therefore the mean rainfall at that station. It is, however, nothing like it. From Table II. and fig. 2 we see that the rainfall over England, generally, during those ten years was 1·5 per cent. above the average, upon which evidence we are bound to reduce the observed mean in that proportion, and then the average becomes 152 inches instead of 154. Even this, however, is not correct; for we pointed out in condition (2) that the same years, or groups of years, are not similarly wet in all parts of the country. Referring, therefore, to Table IV. we find that at the nearest station to Seathwaite, Kendal, the decade in question was 7 per cent. above the thirty-year mean; hence, on the supposition that the Kendal values are applicable to this station, we have to reduce 154 inches by 7 per cent. instead of by 1·5 per cent., and hence the probable mean comes out 141·8 inches.

Now most fortunately we can test the accuracy of this calculation in three ways.

(1) The mean fall at Seathwaite in the previous decade was 126·98; from the Kendal observations the fall in that decade was 10 per cent. less than the mean; therefore $\left(\frac{126{\cdot}98}{0{\cdot}90}=141{\cdot}09\right)$ we find the probable mean comes out 141·1 from this decade, and 141·8 from that of 1860–69. They thus agree within less than an inch, or one half per cent.

(2) The fall at Seathwaite has now been continuously observed for twenty-six years, viz. from 1845 to 1870 inclusive; the mean of the whole twenty-six years' observations is 140·03.

(3) This value, corrected according to the Table in our 1866 Report, becomes 141·44, agreeing *exactly* with that indicated by the decades 1850–59 and 1860–69.

This example proves three points:—(1) the great degree of accuracy which is attainable by proper methods; (2) the care requisite to secure it; (3) the serious errors inseparable from the use of mere arithmetical averages without reference to secular changes.

These observations, however, must of course be taken as general results, and not be construed as having any bearing on the relative rainfall even of proximate stations, the rainfall of which will vary considerably according to local circumstances.

Hence it will be seen that the probable average at Seathwaite is 141 inches

instead of 154, or 7 per cent. less. A similar, but generally less correction, may be required for other stations. The figures in Table V. must not therefore be considered as showing the mean fall at the several stations, but only as approximations generally pretty close. The data in our possession, if corrected in accordance with the method explained, would afford more accurate results, but the investigation is altogether beyond our present resources.

Large tracts of Ireland, and even of Scotland, are still without observers; much has recently been done to remedy these deficiencies, but there are still many localities where observations are very much wanted; we shall gladly receive any offers of assistance from those who have residences or property in those parts, and our Secretary will readily advise them as to instruments.

Third Report on the British Fossil Corals. By P. MARTIN DUNCAN, *F.R.S., F.G.S., Professor of Geology in King's College, London.*

Introduction.—There can be no doubt that the palæontology of the Madreporaria of the Palæozoic strata is in a condition of profound confusion. When these Reports were commenced, the very excellent descriptions and classification of the Palæozoic Corals by MM. Milne-Edwards and Jules Haime, strengthened by those of M. de Fromentel, appeared to have satisfied palæontologists, and they were received and adopted without much demur. But during the last three or four years a series of more or less important attacks has been made upon the views of those distinguished authors; consequently opinions respecting many important matters in the palæontology of the Palæozoic corals are in a very unsatisfactory state.

L. Agassiz, A. Agassiz, and now Count Pourtales would remove the Tabulata from the list of Madreporaria. Mr. Kent and I doubt the propriety of establishing the Tabulata as a group. Count Keyserling demurred years since at receiving the long septaless Tubulata amongst the Madreporaria, and, after due examination, I agree with him in relegating them to the Alcyonaria.

Working amongst the Rugosa, I have shown that they do not invariably characterize Palæozoic strata, for some of the types have persisted, and no reasonable doubt can be entertained concerning the descent of the Jurassic Coral-fauna from the Palæozoic.

The genus *Palæocyclus* has been shown not to belong to the Fungidæ, but to the Cyathophyllidæ. Genera with the hexameral arrangement of septa have been found in Carboniferous and Devonian strata.

Lindström's interesting researches respecting the operculated condition of some Palæozoic corals require most careful study and much following up, and the assertion of L. Agassiz respecting the hydroid relationship of those Rugosa which have tabulæ demands further inquiry *.

Ludwig, of Darmstadt, has added to the confusion by not acknowledging the received classification in the least; and in his able enthusiasm (anti-

* G. Lindström, pamphlet translated by M. Lindström from the original Swedish, 'Geological Magazine,' 1866, p. 356. He notices that Guettard first described an operculum in a rugose coral, and that then Steenstrup saw one in a *Cyathophyllum mitratum*. Lindström produces evidence respecting the genera *Goniophyllum, Calceola, Zaphrentis, Hallia*, and *Favosites* (see also p. 406 *et seq.*).

Gallican enough) he alters generic and specific names, employing sesquipedalian Greek, and even absorbing the original authors ('Palæontographica,' H. von Meyer, 1866).

Thus he confuses *Stromatopora concentrica*, Goldfuss, with the Madreporaria, and calls it *Lioplacocyathus concentricus*. Fortunately Ludwig gives a plate of it (tab. lxxii. fig. 1), and thus proves the total absence of all structures which differentiate the Madreporaria. After thus dignifying a rhizopod, we may be prepared for any thing.

The same author figures a form which is clearly that of *Heliolites porosa*, and calls it by the extraordinary name of *Astroplacocyathus solidus*, Ldwg. It appears that this naturalist studied this eminently cellular type from a cast, hence the term *solidus*. Again, in tab. lxxi. fig. 2, Ludwig delineates a good specimen of *Cyathophyllum hexagonum*, Goldfuss, 1826, and with surpassing coolness names it *Astrophlœothylacus vulgaris*, Ldwg. He then confounds a species of *Lithostrotion* and *Smithia Hennali*, E. & H., in one genus, *Astrophlœocyclus*, Ldwg.

The student of the Silurian corals will be surprised perhaps to find that, according to Ludwig, *Halysites catenularia*, Ed. & H., the *Catenipora escharoides* of Lonsdale, is transformed into *Ptychophlœolopas catenularia*, Ludwig, doubtless on the principle that having found such a very distinguished generic title, the compiler of it has the right to eclipse the discoverers of the form. *Chætetes*, which some of us consider to belong to the Alcyonarian group, as it has no septa, Ludwig decorates with the title "*Liophlœocyathus*."

In his sixty-ninth plate, fig. 5, there is a very good representation of a coral ordinarily known as *Acervularia Troscheli*, Ed. & H. This form was inaccurately described by Goldfuss, who called it *Cyathophyllum ananas*. Now the authorship is settled by this Alexander, who cuts the knot by claiming the species as his own, under the title of *Astrochartodiscus ananas*, Ludwig!

Then *Pleurodictyum problematicum*, Goldfuss, is altered into *Tæniochartocyclus planus*, Ldwg.

To render matters easier to the student, Ludwig associates *Acervularia luxurians* and *Cyathophyllum helianthoides* in one genus, *Astroblascodiscus*, and of course places his name after the species. Then *Cyathophyllum cæspitosum* becomes, under the same lexicographic hands, *Astrocalanocyathus cæspitosus*, Ludwig! In another place *Cyathophyllum helianthoides*, Goldfuss, just mentioned under the term *Astroblascodiscus*, appears as *Astrodiscus*. Lonsdale's *Cystiphyllum cylindricum* is turned into *Liocyathus catinifer*, Ldwg.

This author, moreover, appears to hold a brief against the belief in the quadrate arrangement of the septa in the Rugosa, and, in a manner which is excessively arbitrary and artificial, terms such and such septa primaries, so as to reduce the cycles to sixes. In spite of the evidence of great industry given by Ludwig, I cannot accept his classification, nor do I find his hypothetical septal readings consistent with facts. Nevertheless, Ludwig has contributed to our knowledge of Permian corals, and has discovered some species of genera hitherto supposed to characterize the Carboniferous formation in the Upper Devonian of Germany.

The nature of this Report must therefore be very different to those already presented to the Association. Those reports relating to the Corals of the Mesozoic strata were essentially founded upon observed facts, and upon data which had been more or less before the geological world for years; the generalizations embodied in them were established upon very satisfactory details. But in the present instance there is much uncertainty; there are

vast accumulations of details to be worked out without the existence of a satisfactory classification, and, in fact, the whole subject of the Palæozoic Madreporaria is in too transitional a state for an exhaustive report to be made upon them.

In presenting this Report, therefore, I hope the Association will consider that I have not yet completed my task, and that it will allow me to continue my work and to present other reports when occasion offers. No further grant will be required, as the future reports will deal more with the results of other labourers than with my own.

The present Report is divided into four parts.

I. The consideration of the alliances of the Neozoic and the Palæozoic Coral-faunas.

II. The classification of the Perforata.

III. The classification of the Tabulata.

IV. The Rugosa.

In order to avoid useless repetition of well-known facts, I have referred to them by giving their bibliography, except when they are contained in inaccessible works.

I. The Palæozoic corals of Great Britain have been the subject of many admirable works; they have been largely treated of in the 'Monograph of the British Fossil Corals' (Palæontographical Society) by MM. Milne-Edwards and Jules Haime, and by M'Coy in Sedgwick's great work. Phillips, Lonsdale, King, Sam. Woodward, Parkinson, Martin, Fleming, Portlock, Sowerby, and Pennant have described species in their well-known works, and Kent, James Thomson, and I have contributed some information on the subject of the Scottish corals. But, with the exception of the labours of the last three persons, the literature of the Palæozoic Corals will be found very accessible in the monograph already noticed; any omissions, and a considerable number of new species will be published in my Supplement to that monograph, which I trust will appear year after year, especially as the Supplement to the Mesozoic Corals is now complete (Palæontographical Society).

The vertical range and the horizontal distribution of the species of corals have been worked out by Robert Etheridge, F.R.S., in a work which is now in course of publication (Cat. of Brit. Fossils).

MM. Milne-Edwards and Jules Haime classified the British Palæozoic Corals amongst the sections Aporosa, Tabulata, Tubulosa, and Rugosa. The great section Perforata is not represented in the British strata, but it is in the equivalent American beds.

The only representative of the Aporosa in their classification was one of the Fungidæ, *Palæocyclus* being the genus. It is a Silurian form, and no others of the family have been discovered in the other Palæozoic rocks. The genus has been the subject of a memoir in the Philosophical Transactions, 1867, where its rugose affinities are pointed out, and its cyathophylloid nature also. But the Aporosa are nevertheless represented in the Devonian and Carboniferous rocks by the genera *Battersbyia* and *Heterophyllia* (Phil. Trans. 1867).

The alliances of these forms and of some of the Rugosa with the Jurassic Coral-fauna have been noticed in my Supplement to the Brit. Foss. Corals (Pal. Soc.), part "Liassic," and in the Essay in the Phil. Trans. of 1867*.

* The PALASTRÆACEÆ. Genera *Battersbyia* and *Heterophyllia* (Phil. Trans. 1867, p. 643 *et seq.*, P. M. Duncan).—The so-called cœnenchyma of *Battersbyia inæqualis*, Ed. & H., is like that of *Battersbyia grandis*, nobis, and *B. gemmans*, nobis. It is really nothing

I do not consider that the Tubulosa belonged to the Madreporaria, but that they were Alcyonarians.

It is very certain that some Aporose, Perforate, and Rugose corals have tabulæ, and that their existence cannot remove the forms from their received zoological position into the separate section of Tabulata.

Thus the well-known Aporose coral of the deep sea, *Lophohelia pro-*

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more than portions of *Stromatopora* which enclose the corallites and grow simultaneously with them.

I have altered the generic characters of *Battersbyia*, in consequence of a careful examination of the old and the two new species. It is as follows:—Corallum fasciculate and branching; corallites tall, cylindrical, unequal in size and distance; septa numerous and following no apparent cyclical order.

Endotheca very abundant: it is vesicular, and there are no tabulæ. Epitheca, costæ, and cœnenchyma wanting. The wall is stout, and the septa spring from wedge-shaped processes. The columellary space is occupied by vesicular endotheca. Gemmation extracalicular and calicular from buds having only five septa.

There are three species:—

Battersbyia inæqualis, *Duncan.*	Devonian Limestone; found in pebbles, and not *in situ.*
—— grandis, *Duncan.*	
—— gemmans, *Duncan.*	

In *Battersbyia gemmans* the buds which develop more than five septa grow into corallites, which are destined to bud again from the external wall, and the buds which develop five septa produce other buds from their interseptal loculi; the buds thus developed resemble the corallites with more than three septa. This curious alternation of gemmation has not been noticed in any other genus.

The genera *Battersbyia* and *Heterophyllia* (Phil. Trans. *loc. cit.*) have much in common. They have a stout wall, a vesicular and dissepimental endotheca, delicate septa, very irregular in their number, and neither tabular epitheca nor a quaternary septal arrangement.

The genus *Battersbyia* has nothing to ally it to the Rugosa or the Tabulata. *Heterophyllia* has in some of its species the solitary septum or vacancy which is so often observed in the Cyathophyllidæ. Its costal wall and endotheca connect it with the Mesozoic and recent Astræidæ.

The singular septal development of *Battersbyia* is witnessed in the fasciculate Liassic Astræidæ. The pentameral arrangement of the Battersbyian septa is not unique, for *Acanthocœnia Rathieri*, D'Orb., of the Neocomian has only five septa, and so have the species of *Pentacœnia*, all of which are from the same great formation. The proper Liassic and some of the Lower Oolitic Thecosmiliæ and Calamophylliæ represent and are allied by structure to *Battersbyia*. The highly specialized characters of the Heterophylliæ, especially of *H. mirabilis*, could hardly be perpetuated during great and prolonged emigrations, so that the genus appears to be without representatives in the secondary rocks. Its alliance to *Battersbyia*, however, is evident enough.

The genus *Heterophyllia*, M'Coy, was examined by me in 1867, and the study of several new species of it rendered a fresh diagnosis requisite.

The following description of the diagnosis appeared in my essay on the genera *Heterophyllia*, &c., already noticed:—

"The corallum is simple, long, and slender. The gemmation takes place around the calicular margin, and is extracalicular. The septa are either irregular in number and arrangement, or else are six in number and regular. The costæ are well developed, and may be trabecular, spined, and flexuous. The wall is thick; there is no epitheca, and the endotheca is dissepimental."

The genus may be subdivided into a group with numerous septa, and a group with six septa.

In the first the rugose type is faintly, and in the last the hexameral arrangement is well observed.

The dense wall and the dissepimental endotheca prove that the type of the Mesozoic Coral-fauna was foreshown.

The endotheca varies in quantity in the different species, and it resembles the tabular arrangement; but even when this is the case and the cross structures are well developed and numerous, they do not stretch over the axial space, so as to shut out cavities as if they were floors; they do not close in the whole of the visceral and interlocular

lifera, Pallas, sp., may have some of its corallites subdivided by perfect tabulæ; the species of *Cyathophora* of the Oolites also; yet it would be a most objectionable and improper proceeding to remove these genera from their recognized alliances. I found an *Astræopora* in the Museum at Liverpool with tabulæ; and Mr. Kent has pointed out the perforate affinities of *Koninckia* and of the form he has published. Some Rugosæ have perfect tabulæ, others have them not; and in *Cyclophyllum* and *Clisiophyllum* dissepiments exist in some parts of a corallum and not in others, where they are replaced by tabulæ. This interesting fact may be gleaned from James Thomson's sections taken from the Scottish corals.

Nevertheless there are forms which are essentially tabulate, and not rugose, but which, so far as their hard and septal structures are concerned, may be aporose in one instance and perforate in another; for instance, *Columnaria* and *Favosites*. These forms may still *provisionally* be considered Tabulata.

Alliances.—The Lower Cretaceous and Neocomian corals appear to connect the oldest and the newest faunas, and to form an excellent starting-point both for the study of the Tertiary as well as for the Palæozoic forms. It will be readily observed that the succession of genera and species from the lower Cretaceous horizon to the present day is gradual; and that although many forms died out, still the general appearance of the consecutive faunas, such as those of the Middle and Upper Cretaceous, the Nummulitic, the Oligocene, the Miocene, the Pliocene, and of the two great faunas of the present day, presents a remarkable similarity of what is usually called "facies." The similarity between the Lower Cretaceous fauna and that of the Miocene has been treated of elsewhere *, and the analogies of the mid-tertiary corals and those of the Pacific also. Moreover since the last Report was read the distinction between reef, deep-sea, and littoral corals has been more satisfactorily established, and the reason why consecutive faunas upon the same areas could not possibly be identical, even as regards the genera, has been explained †.

As the Coral-faunas are studied from those of recent date backwards in time, extinct forms are met with which gradually fill up the spaces in the very natural received classification, and it is perfectly evident that the existing species were foreshadowed in the past. A great number of existing species lived in the so-called Pliocene, and not a few in the Miocene ‡. Reuss's admirable researches amongst the vast reefs which are of an intermediate age between the Flysch and the typical coral districts of the Miocene age, have carried back the homotaxis of the existing coral areas to a time which has hardly been recognized by British geologists, but whose fossils are clearly

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cavities in a horizontal plane. In some species the dissepiments are curved, and are as incomplete as when they are more or less horizontal in others, and vesicular endotheca exists, more or less, in nearly all the forms.

There are no true tabulæ, and the dissepiments do not interfere in any way with the passage of the septa from the lowest part of the corallum to the calice.

There are eight species of *Heterophyllia*:—

Heterophyllia grandis, *M'Coy.*	Heterophyllia M'Coyi, *Duncan.*
—— ornata, *M'Coy.*	—— Lyelli, *Duncan.*
—— granulata, *Duncan.*	—— mirabilis, *Duncan.*
—— angulata, *Duncan.*	—— Sedgwicki, *Duncan.*

The first two are found in the Carboniferous limestone of Derbyshire, and the others in the Scottish Carboniferous strata (see Phil. Trans. 1867, p. 643 *et seq.*).

* West-Indian Foss. Corals (P. M. Duncan, Quart. Journ. Geol. Soc. xxiv. p. 28).

† Coral Faunas of Europe (Quart. Journ. Geol. Soc. xxvi. p. 51 *et seq.*).

‡ Corals of Porcupine Expedition (Proc. Royal Society, xviii. p. 289).

represented at Brockenhurst. In the great reefs of the Castel-Gomberto district there are the remains of a larger coral-fauna than that which now exists in the Caribbean Sea; and although a profound Flysch exists between them and the reefs in the Oberburg district, indicating great oscillations of the area and vast changes in the life of the time, still the genera which contribute so largely to the formation of modern reefs are found represented in abundance in the lowest reefs, which clearly belong to the Nummulitic period.

Our Eocene corals and those found at Brockenhurst are the stunted offshoots of the faunas which flourished at Oberburg and in the Vicentine, but nevertheless some of their species are closely allied to those of much later geological date.

Without the assistance of the labours of Reuss and D'Achiardi zoophytologists could not have imagined that the well-known coral-faunas of the Hala Mountains of Sindh, of the Nummulitic deposits of the Maritime Alps and Switzerland, and of the London and Paris basins were but fractions of a fauna which was probably richer in species than any modern coral tract; and this welcome aid proves the impropriety of neglecting foreign palæontology, even when writing reports like the present, and which treat of the productions of the rocks of a small area. The impossibility of comparing with any satisfaction the Nummulitic coral-fauna and that of the Upper Chalk is obvious; because the Nummulitic fauna, so far as it is known to us, was either a reef or a comparatively shallow-water one, whilst the corals of the Upper Chalk were dwellers in a deep sea, where reef species cannot and could not exist. We must seek to compare the Upper Cretaceous corals with the deep-sea forms of the Nummulitic, but unfortunately they are not yet found*.

The Lower Cretaceous corals of Great Britain were the contemporaries of the reef-builders of the Gosau and equivalent formations, and thus deep-sea and reef species were contemporaneous, as they are at the present time, but they were separated by wide distances. The comparison of the reef-fauna and that of the deep sea is in this instance as futile as it would be at the present time; but we may compare the reef-fauna of Gosau with that of the Nummulitic, Oligocene, Miocene, and existing reefs, and not without benefit and good results, for there are persistent species which unite the whole together.

A comparison may also be instituted between the deep-sea coral-faunas of the Chalk and those which flourished at corresponding depths in the succeeding geological epochs. Thus, thanks to Messrs. Wyville Thomson, Carpenter, and Jeffreys, I have been able to assert the extraordinary homologies between the deep-sea Cretaceous corals and those which now exist to the west of these islands. These results are being published by the Zoological Society. The present arrangement of coral genera in and about reefs was foreshadowed as early as the Eocene, and such assemblages of genera existed in those old reefs as would characterize the coral life of atolls in the Caribbean Sea and in the raised reefs of the Pacific Ocean. The genera *Madrepora*, *Alveopora*, *Porites*, *Heliastræa*, and *Millepora* were represented in the Oberburg, and their species constitute the bulk of existing reefs. It is important to be thus able, from the labours of MM. Milne-Edwards, J. Haime, and Reuss, to determine the existence of Perforate and Tabulate corals in the earliest tertiaries, for interesting links are thus offered to the palæontologist by which the older and the newer faunas are connected. Such researches diminish the importance of the break between the early Tertiary fauna and the present, and also, to a

* See P. M. Duncan on a new Coral from the Crag, and on the persistence of Cretaceous types in the deep sea (Quart. Journ. Geol. Soc. xxvii. pp. 369 & 434).

certain extent, that between the Palæozoic and recent faunas. Thus the finding of species of the great Perforate genus *Madrepora* in the Oberburg carries the genus a step further back than their discovery in the Oligocene of Brockenhurst, and when taken into consideration with the presence of the *Stephanophyllia*, a perforate simple coral, in the Crag, Eocene, and Lower Cretaceous deposits, and with *Actinacis*, a highly developed compound form, in the Lower Cretaceous strata of Gosau, the immense break between the next form of the family and the existing is materially diminished. The next form is not met with until the Carboniferous deposits of Indiana are reached in a downward course; and we owe to the late Jules Haime the knowledge of the structures of *Palæacis cuneiformis*, Haime, MS., from Spurgeon Hill, Indiana. It is indeed remarkable that the vast coralliferous strata which intervene between the Carboniferous and the Lower Chalk should not present a satisfactory proof of the existence of those members of the existing great reef-building family. There is a curious fact which may be taken for what it is worth in considering the absence of genera which have been represented in some ancient deposits and which have not been found in intermediate strata. Thus the existing West-India reefs contain abundance of the species of the genus *Madrepora* and *Millepora*; indeed they, with the forms of *Porites*, constitute the bulk of the formations. Now, although *Porites* is common in the Miocene reefs of the area, the others are very rare, for the coral structures were principally composed of tabulate forms and Heliastræans. Yet we know that before the Miocene reefs flourished, Madreporæ and Milleporæ were common enough; they were living all the while in other coral tracts. But the break between the Palæozoic and the Lower Cretaceous forms cannot be bridged over without investigating the value of the classification which separates the most closely allied subfamily of the Perforata, although the Perforata are found in the Great Oolite.

II. The Perforata characterized by a porous cœnenchyma and other tissues present many modifications of their hard parts. Some approach the Aporosa, and others would hardly be considered corals by the uninitiated on account of the sponge-like reticulations of the skeleton. The genus *Madrepora* is defined as follows by MM. Milne-Edwards and Jules Haime:—

The corallum is compound and increases by budding. The cœnenchyma is abundant, spongy, reticulate, slightly or not at all distinguishable from the walls, which are very porous. The visceral chambers are subdivided by two principal septa, which meet by their inner margins, and are more developed than the others.

The septa, especially the two largest, although perforated, are continuous, and very often lamellar.

MM. Milne-Edwards and Jules Haime distinguish the Poritidæ in the following manner:—

The corallum is compound, and entirely formed of a reticulate cœnenchyma, which is formed of trabeculæ and is porous. The corallites are fused together by their walls, or by an intermediate cœnenchyma, and they multiply by budding, which is usually extracalicular and submarginal.

The septal apparatus is always more or less distinct, but never completely lamellar, and is formed by a series of trabeculæ, which constitute by their union a sort of lattice-work. The walls present the same structure as the septa. The visceral chambers sometimes have rudimentary dissepiments, but are never divided by tabulæ.

This family is divided into two subfamilies—

1. The Poritinæ, with a rudimentary or absent cœnenchyma.
2. The Montiporinæ, with a well-developed cœnenchyma.

It will be noticed, when specimens of Montiporinæ and Madreporæ are compared, that the distinction is in the absence of the two large and not very perforate septa in the case of the first-mentioned group, and it is clear that the excessively trabecular character of its septa, cœnenchyma, and walls is characteristic. Moreover the Montiporinæ are recent forms.

The genus *Litharæa* amongst the Poritinæ approaches *Madrepora*, however, and its septa are often so lamellar that they resemble those of some Heliastræans amongst the Aporosa. Here the distinction between the forms becomes limited. The two great septa are not extended to the median line in *Litharæa*, and there is scanty cœnenchyma, but still there is some. The columella of *Litharæa* is simply formed by the union of trabeculæ from the septal ends.

Now *Protaræa vetusta*, Hall, and *Protaræa Verneuili*, Ed. & H., Lower Silurian corals from Ohio, only differ from the species of *Litharæa* by having more aporose septa and some cœnenchymal protuberances*. It is necessary, however, on account of the comparatively late appearance (so far as our investigations has as yet gone) of *Madrepora* and *Litharæa*, whilst admitting the extraordinary relation of the last-named genus to *Protaræa*, to examine another of the Jurassic Perforata.

The genus *Microsolena* of the Poritinæ carries the excessively trabecular type of the Poritinæ as far back as the Great Oolite; it is of course one of the extreme forms, and most remote from *Madrepora*. It has more or less confluent septa, and nothing like the styliform columella of *Protaræa*. Thus *Palæacis*, a form of the Madreporinæ, and *Protaræa*, a type of the Poritinæ, are still unsatisfactorily disconnected by intermediate species with their allies in the secondary rocks. But, on the other hand, it is something to be able to show an anatomical connexion between the *Protarææ* of the Lower Silurian and the *Microsolenæ* of the Jurassic and of the *Litharææ* of the Nummulitic rocks, and between *Palæacis* and the Turbinarians of the group Madrepora, of which *Actinacis* is the oldest (Lower Chalk)†. It shows that the reticulate or perforate corals existed amongst the first known coralliferous rocks, that the scheme of their organization has been perpetuated to the present day through many kinds of variations, but with a great break, which is owing to the imperfection of the geological record.

III. The Tabulata, which form such large portions of many modern reefs, were, as has been already noticed, in existence during the Miocene‡, the Oligocene§, and the Eocene‖. They were, of course, not found amongst the deep-sea deposits of the Cretaceous period, such, for instance, as our White Chalk; but Reuss found the genera in the reefs of Gosau. *Heliopora Partschi*, Reuss, sp.; *H. macrostoma*, Reuss, sp.; *Polytremacis Blainvilleana*; *P. bulbosa*, d'Orb.: these are not uncommon in the reefs which were in relation with the *Hippurites*, and the last coral genus lived during the Eocene. Reuss established a genus in 1854 for some compound, massive corals, with prismatic corallites with thick imperforate walls. The calices are without radiating septa and have no columellæ. The tabulæ are very irregular, some being complete and others uniting obliquely with their neighbours. The septa are represented by trabeculæ. This Lower Cretaceous genus he named *Stylophyllum*, and will be considered further on.

* See Hist. Nat. des Corall. vol. iii. p. 185.

† M. Lindström has lately described a *Calocystis*, a perforated coral from the Silurian.

‡ See Duncan, West-Indian Fossil Corals (Q. J. Geol. Soc.); Reuss, Corals of Java, &c.

§ Reuss, *op. cit.*, and Duncan (Pal. Soc. Tertiary Corals of Brockenhurst).

‖ MM. Milne-Edwards and Haime, Hist. Nat. des Corall. &c.

Pocillopora, so common a genus amongst the Indo-Pacific reefs, was found in the West-India Miocene, the Javan deposits, and at Turin and Dax. It is considered to be allied to *Cœnites* by Milne-Edwards, but Jules Haime doubted the Zoantharian characters of the last-named genus, which is Palæozoic. *Seriatopora*, a modern genus, does not appear to have been found fossil; but it is closely allied, according to the received opinion, with *Rhabdopora*, *Dendropora*, and *Trachypora*, all Palæozoic genera, the first being Carboniferous and the others Devonian. *Millepora*, the great reef-building genus of the West Indies, can be traced into the Lower Tertiaries, and is closely allied to the *Heliopora* already mentioned, and by structure to the *Heliolites* of the Palæozoic period.

Between the Lower Cretaceous reefs and the Palæozoic there were the Devonian, the Oolitic, the Lower Liassic, the Rhætic, and the St. Cassian and the Muschelkalk reefs, but not a trace of a tabulate coral has been recorded from them, in spite of the affinities of the modern and most ancient genera of the Devonian. *Cyathophora* has tabulæ, but its alliances are with the Astræidæ. On examining the lists published in my last Report, the absence of tabulate corals in the whole of the Mesozoic strata of Great Britain will be apparent, and I have not been able to distinguish any foreign forms belonging to that vast age (except our *Holocystis elegans*, Ed. and H.), of which notice will be taken in treating of the Rugosa and the species of *Columnastræa*.

Just as the Thecidæ, Favositidæ, and Halysitinæ formed the reef-builders of the tabulate fauna of the Palæozoic times, so Milleporidæ and Seriatoporidæ contribute to the recent reef-fauna; but these last genera had species in the Palæozoic fauna, so the break of the end of the Permian or Carboniferous periods was not complete so far as the Tabulata were concerned. The absence of them from the successive secondary reefs that have been examined by palæontologists has probably been produced by the destructive fossilization which is so common in existing reefs, and by the real absence of the forms from certain reef-areas of which there is an example (see 'West-Indian Fossil Corals,' Duncan).

The Tabulata were as abundant in the Palæozoic periods as during the Tertiary epochs, and the ancient and modern genera and species have certain characters which differentiate them more or less from all other coral forms.

MM. Milne-Edwards and Jules Haime characterize the Tabulata as follows (Hist. Nat. des Corall. iii. p. 223):—

The corallum is essentially composed of a well-developed mural system, and the visceral chambers are divided into a series of stages by transverse floors, which act as complete diaphragms.

The septal apparatus is rudimentary, and is either completely deficient or only represented by trabeculæ which do not extend far into the intertabular spaces.

The lamellar diaphragms, floors, or tabulæ, which close the visceral chamber of the corallite at different heights, differ from the dissepiments of the Astræidæ by not depending in any manner upon the septa, by closing completely the space below, for they stretch uninterruptedly from side to side, instead of simply occupying the interseptal loculi.

The septal apparatus does not affect the Rugose type, but that characteristic of the Perforata and Aporosa. The forms classified under the section of the Tabulata are very numerous, and hence the importance of determining whether they can be undoubtedly allied with the rest of the Actinozoa.

Many years have elapsed since Agassiz expressed his opinion, founded upon direct observation, that the *Milleporæ*, an important genus of the Tabulata,

were not Actinozoa, but Hydrozoa, and lately he has reasserted this statement. If *Millepora* is one of the Hydrozoa, those tabulate forms which resemble it in structure, such as *Heliolites*, must reasonably be associated with it in classification. The importance, then, of determining this point is very great, and unfortunately it is accompanied by many difficulties. Before proceeding to criticise Agassiz's remarks, it is necessary to examine the nature of the structures of the genera associated with *Millepora*, or, in fact, to review the classification of the Tabulata, and to note their affinities with the other sections. Milne-Edwards and Jules Haime divide the Tabulata into four families:—Milleporidæ, Seriatoporidæ, Favositidæ, Thecidæ.

The principle upon which this classification is founded is philosophical and natural to a certain degree. The first two families have more or less cœnenchyma between the corallites, and the last two have little or none, the corallites being soldered together by their walls.

The genus *Pocillopora* unites the two divisions, for it belongs to the Favositidæ, and yet has a compact cœnenchyma on the surface of the corallum.

The classificatory value of the presence of cœnenchyma in the whole of the Madreporaria may be estimated by examining the scheme of MM. Milne-Edwards and Jules Haime.

When treating of the Madreporidæ (Hist. Nat. des Corall. vol. iii. p. 91), they subdivide them into Eupsamminæ without an independent cœnenchyma, Madreporinæ and Turbinarinæ with a very abundant cœnenchyma.

The Poritidæ they subdivide into the Poritinæ without cœnenchyma, and the Montiporinæ with an abundance of that structure in the spongy or alveolar form.

The Euphylliaceæ (Ed. & H. *op. cit.* pp. 184 & 197) have such genera as *Barysmilia* and *Dichocœnia*, associated with *Dendrogyra, Gyrosmilia, Pachygyra, Rhipidogyra,* which have or have not much cœnenchyma.

The Stylinaceæ are divided into independent, "empâtées," and agglomerate. The independent genera have no cœnenchyma; the "empâtées" possess it in the extreme so as to merit the term peritheca.

The agglomerate have an excess of exotheca, but some genera are admitted which are united by their walls, and are therefore without exotheca or cœnenchyma. Thus *Phyllocœnia* has an exotheca quite cœnenchymatous, and *Astrocœnia* has none. The corallites of *Elasmocœnia* have large mural expansions, and those of *Aplocœnia* are soldered by their walls. *Heterocœnia* and *Pentacœnia* present the same anomalies.

The Astræinæ present such genera as *Aphrastræa* and *Septastræa*, the one with and the other without extramural tissue, and *Heliastræa* and *Solenastræa* with and *Isastræa* without the same structure.

It is then evident that the presence or absence of cœnenchyma had different significations in the estimation of the distinguished French zoophytologists.

It is evident that the structure of the corallites of Isastrææ and their deficiency in cœnenchyma in comparison with the Heliastrææ and Solenastrææ cannot be of any very great organic significance; for the corallites of Heliastrææ occasionally grow so close together as to produce absorption of the exotheca and costæ, and the same occurs in the Astrocœniæ. The presence of exotheca, peritheca, and cœnenchyma (for they are grades of a particular structure) depends very much upon the habits of the corallum, and the notion of teleology can hardly be separated from the consideration of this presence and absence. Certainly to separate great groups by the presence or absence of cœnenchyma is not natural. It may be very useful to the classificatory student, because the limitation of forms is the prevailing want; but it is not

so to the biologist, for these mixed and unnatural limitations and separations only form gaps in his argument, which require bridging over.

The Favositidæ and Thecidæ, Palæozoic forms, may then be separated, for the purposes of classification, from the Milleporidæ and Seriatoporidæ, which are almost all post-Palæozoic; but this limitation is not to impede the plain course of the palæontologist, who studies from a biological point of view; nor is it to stand in the way of the assertion, that the break between the Palæozoic and younger Tabulata is almost *nil*.

The genus *Millepora* belongs to the Milleporidæ, and the cœnenchyma of its species is very abundant. It is of "a very irregular and spongy structure, rather than tubular" (Ed. & H.). The calices are of very different dimensions on the same corallum. There are no distinct septa, nor is there a columella. The tabulæ are horizontal. These are the diagnostics of the genus according to Milne-Edwards and Jules Hame. A careful examination of the calices of good specimens determines that the trabeculæ, of which the cœnenchyma is composed, often projects into them, in the position of septa; but there is nothing like the regular arrangement as seen in *Heliopora*, or in the Poritidæ of the Perforata. The cells of the cœnenchyma may occasionally be seen to open into the space above the last tabula.

The absence of septa and this relation of the cœnenchyma to the gastric space are most important. The tubular nature of much of the cœnenchyma is evident, and longitudinal sections of some size prove that the spongy nature of it is by no means constant nor uniform.

In *Heliopora*, belonging also to the Milleporidæ, the cœnenchyma is very abundant, and covered here and there with rounded pores arranged more or less regularly and separated by papillose granules. These grains are the extremities of cylindrical "tigelles" which circumscribe the tubules, the calice of which is open at the surface. The calices are circular. The septa are slightly developed, and there are twelve of them. The tabulæ are well developed and horizontal (Ed. & H.). The nature of the cœnenchyma and the distinct septa distinguish this genus from the last. Both of the extinct species have a papillose or striated structure running over the cœnenchymal surface. In all the species the septa do not project far into the calice; but the amount of projection is not sufficient, as a structural peculiarity, in any case to determine more than a specific distinction. Hence MM. Milne-Edwards and Jules Haime when they separate, in their scheme of the Milleporidæ*, *Millepora* and *Heliopora* and other genera from *Heliolites*, *Propora*, and *Lyellia*, the particular Palæozoic genera, they can only be permitted to do so on the plea that the plan renders the genera readily distinguishable. The projection or non-projection is not sufficient to determine a generic difference.

Now *Heliolites* has a beautiful cœnenchyma, very geometric, and not irregular and spongy; its cellules are placed regularly and symmetrically. In most of the species the septa are distinct, and project far inwards, but in *Heliolites Grayi* they are almost rudimentary.

The genus *Polytremacis* links *Heliolites* and *Heliopora* together, for its cœnenchyma is that of the second, and the septa resemble those of the first-named genus. *Polytremacis* is not older than *Heliopora* in the secondary ages, and the septal distinction which cannot expel *Heliolites Grayi* from its genus, and which is improperly allowed to distinguish *Polytremacis* and *Heliopora*, and these and *Heliolites*, may well have been produced by variations in a succession of early secondary forms.

* *Op. cit.* p. 225.

The septal development of *Heliolites* is exaggerated in *Propora*, a genus from the Upper Silurian, and which perhaps lasted into the Carboniferous. The costæ in this genus are well developed, but the cœnenchymal cells are less geometric than in *Heliolites*. The structural relations are of the closest, and the generic distinction is not of the usual generic value. Another Upper Silurian genus, *Lyellia*, represents these symmetrical Milleporidæ in America. The corallite walls are subcostulate and not so costulate as in *Propora*. The septa (12) are well developed, as in *Heliolites* and *Propora* and *Heliopora*, and the cœnenchyma is perfectly vesicular—spongy, in fact, like *Heliopora*. Here, then, in the distant and British and Northern European Silurians, there were closely allied forms varying amongst themselves, but more than the secondary types, the variation having some sort of likeness in both instances. It is impossible not to acknowledge the genetic affinities of all these genera except *Millepora*, of which more will be said, or to hesitate to assert that there has never been a break in the Tabulata, and that the Recent and Palæozoic *Heliopora* and *Heliolites* are very closely allied, the one being the descendant of the other*. *Axopora* is a tertiary genus, and its immense columella, which fills up the corallite inferiorly and leaves but little room in the calice around it, of course prevents the tabulæ from reaching across the axial space. The tabulæ come in contact with but do not perforate the columella, so that this structure grows progressively without any reference to them; they do not form floors upon which a columella is developed†. There are no septa, and the cœnenchyma is reticulate in the extreme. No living analogue of this genus exists, and exception may be taken whether it be a true coral. It has no Palæozoic representatives.

Battersbyia is a very remarkable Palæozoic genus, and has been examined by me‡. MM. Milne-Edwards and Jules Haime§ classify it with the Milleporidæ, but apparently only provisionally; but it will be noticed elsewhere. I have associated *Battersbyia* and *Heterophyllia* together as a new division of the Aporosa of the Astræidæ, under the name of the Palastræaceæ, which are noticed in the first part of this Report.

The Favositidæ are divided by MM. Milne-Edwards and Jules Haime into the following subfamilies: Favositinæ, Chætetinæ, Halysitinæ, Pocilloporinæ. All are presumed to present the following family characteristics:—"The corallum is formed essentially of the lamellar walls of the corallites, and possesses hardly any or no cœnenchyma. The visceral chambers are divided by tabulæ, which are numerous and well developed."

The subfamilies without any cœnenchyma, and those whose corallites form a massive corallum, are the Favositinæ and the Chætetinæ, and the genera whose corallites are not united on all sides the Halysitinæ. The Pocilloporinæ constitute the cœnenchymal subfamily. One of the great difficulties of the zoophytologist appears strongly enough whilst investigating these Tabulata, for the question constantly arises, and can only be answered very unsatisfactorily, are such and such forms really Actinozoa? are they not Polyzoa, Hydrozoa, or of some class which has become extinct, and which has no modern representatives?

Some genera are characterized by the absence of septa. Thus *Chætetes* has long basaltiform corallites, numerous tabulæ which do not correspond in their plane throughout the corallum, no septa, and the reproduction is fissiparous.

* See Huxley's Address, Geol. Soc. 1870.
† Pal. Soc. Tertiary Corals, 3rd Series, P. M. Duncan, pl. vii. figs. 11–15.
‡ Phil. Trans. 1867. § *Op. cit.* p. 244.

Keyserling considered the genus to belong to the Alcyonaria amongst the Actinozoa; but MM. Milne-Edwards and Jules Haime, considering the great analogy between *Chætetes* and *Favosites*, and particularly with *Beaumontia*, "où la présence de cloisons n'est pas contestable"*, determined its position to be amongst the true Tabulata.

The same authors now recognize the necessity of separating *Chætetes* from *Monticulipora*, and assert that the members of the last-named genus increase by gemmation.

The genus *Dania* differs from *Chætetes* in having the tabulæ on regular planes which traverse the whole corallum. This peculiarity is hardly of generic value.

Stellipora (Hall) is not generically different from *Monticulipora*, and the truth of this assertion can be estimated by comparing the diagnosis of the genera given by MM. Milne-Edwards and Jules Haime †.

The differentiation of *Dekayia* (Ed. & H.)‡ and of *Labechia* is also unsatisfactory, and their more or less mammillated cœnenchyma ranges them together by the side of *Stellipora* as subgenera of *Monticulipora*.

Now Jules Haime, when investigating the Oolitic Polyzoa, classified forms without septa and with tabulæ, like *Chætetes* or *Monticulipora*, as Polyzoa, and the beautiful *Stelliporæ* were especially included.

Now the question arises, are there any recent Polyzoa whose soft parts have been examined that have tabulæ? From our knowledge of the recent Polyzoa, it is unsafe to answer this in the affirmative. There is a freshwater species which is said to have tabulæ, but the assertion requires confirmation. The classification, then, of these forms amongst the Polyzoa must be deferred, and I propose to decide against it now.

Beaumontia, the genus noticed above, is distinguished by MM. Milne-Edwards and Jules Haime § as follows:—"This genus is distinguished from all other Chætetinæ by the formation of its tabulæ, which are irregular or vesicular, and it thus resembles *Michelenia*, belonging to Favositinæ." The presence of septa belonging to three cycles is asserted by the same authors, and this fact must remove the genus quite out of the neighbourhood of septaless forms.

The genera of the Chætetinæ were formerly *Chætetes*, *Monticulipora*, *Dania*, *Stellipora*, *Dekayia*, *Beaumontia*, and *Labechia*. It has been shown that *Stellipora*, *Dekayia*, and *Labechia* are subgenera of *Monticulipora*, that *Dania* cannot be separated from *Chætetes*, and that *Beaumontia* has no correct affinity with the others, and that it belongs to another family.

The genera should stand thus:—

CHÆTETINÆ.

Chætetes. Subgenus *Dania*.
Monticulipora. Subgenus *Stellipora*.
,, *Dekayia*.
,, *Labechia*.

But the subgeneric names should be dropped.

This result is interesting because it eliminates *Beaumontia* and makes a compact series, the affinities of which are not Polyzoan, but which may be Alcyonarian or Hydrozoan.

The long tabular or basaltiform corallites of *Chætetes* and its allied forms,

* *Op. cit.* pp. 271.
† *Op. cit.* vol. iii. pp. 272, 281.
‡ Ibid. p. 283.
§ *Op. cit.* vol. iii. p. 282.

and their more or less horizontal and perfect tabulæ, recall the Tubiporinæ amongst the order of the Alcyonaria.

The Alcyonaria are Actinozoa which are separated by MM. Milne-Edwards and Jules Haime from the Zoantharia on account of the pinnate structure of the tentacles, and from these important organs being invariably eight in number.

The zoantharian tentacles, on the contrary, are simple or irregularly ramified, and increase in number with age.

The Alcyonaria are divided into the families of the Alcyonidæ, the Gorgonidæ, and the Pennatulidæ.

The first two families have an adherent corallum, and the last consists of free forms.

The Alcyonidæ have no hard central axis, but this characterizes the Gorgonidæ.

Now the Cornularinæ, Telestinæ, and Alcyoninæ, subfamilies of the Alcyonidæ, are clearly allied to the Tubiporinæ by their soft structures; but the hard external structures of this subfamily are only faintly shown in the spiculate scoriaceous conditions of the external tegument of *Nephthya*, *Spoggodes*, and *Paralcyonium*. The polypes of *Nephthya* and *Paralcyonium* enter their spiculate and dense external covering when they contract; but the hard structures of *Spoggodes celosia*, Lesson, are very slightly developed.

Tubipora (pars), Linnæus.

Tubipora, Lamarck.

The genus has been examined by MM. Milne-Edwards and Jules Haime with their usual care and acumen.

The specimens of *Tubipora* are so common that the descriptions of these authors concerning the hard parts of the corallum can readily be followed.

The corallites are formed principally by a tabular wall, the tissue of which is calcareous and readily fractured. There are no septa, but there are rudimentary tabulæ, which cut off the visceral cavity into more or less perfect stages. The corallites are cylindrical, and usually attain an equal height; but they do not touch each other, for they are united by a peritheca, which is only seen here and there in distinct floors. The budding takes place from the connecting peritheca, which is therefore a true cœnenchyma, and not like that of *Solenastræa*. Were the corallites in contact the appearance of *Chætetes* would be presented; so that the presence of the cœnenchyma is the differentiating structure. It is only of generic value, and thus there is a very strong reason for associating the Chætetinæ and all the other fossils with long tubular structures, no septa, and tabulæ with the Alcyonidæ in the subfamily Tubiporinæ and near the genus *Tubipora*. These remarks are subject, of course, to the consideration whether the views of Agassiz already noticed are correct.

Reuss's genus *Stylophyllum* (Gosau Chalk) cannot be associated with the Alcyonidæ, for the species has septa. The corallites are united by their walls without there being a cœnenchyma, and the walls are imperforate. The junction of the corallites takes place by means of an epitheca.

The junction may occur at any part of the corallite.

The resemblance of *Stylophyllum* to some of the Halysitinæ (Ed. & H.)* necessitates an examination of their structural peculiarities.

* *Op. cit.* vol. iii. p. 286.

MM. Milne-Edwards and Jules Haime differentiate the Halysitinæ as follows:—

"The corallum is compound, but its corallites unite imperfectly, and constitute lamellar expansions or long fasciculi; they are either free on two sides, or are united together by '*expansions murales*.'"

The septa are small, but usually very distinct; finally the walls are well developed and aporose.

The genera are:—*Halysites*, Fischer; *Syringopora*, Goldfuss; *Thecostegites*, Ed. & H. (*Harmodites*, Michelin); *Conostegites*, Ed. & H.; *Fletcheria*, Ed. & H.

Halysites. The species are invariably formed by corallites which are joined on two sides, and which in transverse outline resemble links of a chain. The epitheca is very strong, and unites the corallites perfectly where they are in contact from the base to the calice. Septa 12. Tabulæ horizontal and well developed. (Silurian.)

Thecostegites. The corallites have septa, horizontal tabulæ, and an exotheca unites them, and it is more or less tabular in structure, and exists in stages like the *Tubipora*. In *T. parvula* the cœnenchyma is nearly compact. (Devonian.)

Conostegites. There are numerous septal striæ, which mark also the smooth and convex surfaces of the tabulæ. The tabulæ are more or less infundibuliform, and the epitheca unites the corallites here and there.

Syringopora. The corallum is fasciculate; the corallites are cylindrical and very long, parallel, and free laterally, except where horizontal tubes connect them. The walls are well developed, and clothed with a strong epitheca; septa exist. The tabulæ are infundibuliform.

Fletcheria. The corallum is fasciculate; the corallites are cylindrical, close, and long. The epitheca is complete; septa exist. Tabulæ horizontal and well developed. No intercorallite tubes or expansions of epitheca. Gemmation calicular.

It is evident that some of these genera are very slightly allied; for instance, *Syringopora* and *Fletcheria*, and both of them and *Halysites*.

Halysites, with its stout epitheca and simple tabulæ with non-tubular joints, is a very definite form.

Thecostegites should belong to the Milleporidæ.

Conostegites, with infundibuliform tabulæ, is related to *Halysites* as *Michelinia* is to *Favosites*.

Fletcheria is altogether aberrant.

The Halysitinæ comprehend, according to this analysis, *Halysites*, Fischer; *Stylophyllum*, Reuss; *Conostegites*, Ed. & H.

The genera *Syringopora* and *Fletcheria* will be considered further on.

The subfamily of the Pocilloporinæ contains the genera *Pocillopora* and *Cœnites*.

Pocillopora has septa (and my specimens show 12), which, even in fossil specimens, mark the top of the tabulæ. There is a columellary swelling on its tabulæ. The cœnenchyma is very stout and thick in old portions of the corallum, less so where growth has just ceased, and the cœnenchyma barely exists where the corallites or calices are developing. It is cellular at first, and then fills up with calcite and other coral salts.

Fossil forms have been described by Reuss and myself from the Cainozoic formations.

Cœnites resembles *Pocillopora* in a certain density of its cœnenchyma, but differs in only having three tooth-like septa, like the genus *Alveolites*.

The number of septa and the habit of growth of the two genera separate them very widely; and the propriety of connecting the last-named one with the Milleporidæ must be considered.

There are four genera in the family of the Seriatoporidæ:—*Seriatopora, Dendropora, Rhabdopora, Trachypora.*

The family is characterized by the continual growth of the lower parts of the corallites and the rarity of tabulæ.

Seriatopora is a recent genus, and therefore those associated with it must be carefully examined.

Dendropora, Michelin, is clearly too closely allied to *Rhabdopora* to be separated generically.

Rhabdopora, formed for the *Dendropora megastoma,* M'Coy, by MM. Milne-Edwards and Jules Haime, has only one species, the diagnosis of which is as follows:—

Rhabdopora megastoma, M'Coy, sp.—The corallum is branching. Branches four-sided, starting from the stem at an angle of 70°, and very equal. Cœnenchyma granulated or subechinulated and obscurely striated. Calices in vertical series on each face of the branches. Septa (teeth) 12 in number and subequal.

It is impossible to separate this from *Seriatopora,* for the four-sided suture of the branches is only a specific (if that) distinction.

Trachypora appears to be an Alcyonarian.

The distinction between *Pocillopora* and *Seriatopora* is not generic, and therefore these genera and *Dendropora* (for *Dendropora* and *Rhabdopora* are equal, and the first name is the oldest) are absorbed in one. Oken's name *Acropora* (1815) may be used as the generic term:—ACROPORA (*Seriatopora,* Lamarck; *Pocillopora,* Lamarck; *Dendropora,* Michelin; *Rhabdopora,* Ed. & Haime).

All the species of the absorbed genera should take the generic name of *Acropora,* and the family becomes that of the Acroporinæ. Thus the sharp distinction between the recent and Palæozoic forms is partly smoothed down, and the old Dendroporæ and Rhabdoporæ were doubtless the ancestral forms of the recent Acroporæ. *Cœnites* cannot be associated with the family.

The family of the Thecideæ is characterized by well-formed septa, which are prolonged throughout the visceral chamber, well-developed tabulæ, which grow like dissepiments upon the sides of the septa, and these last do not spring from the upper surface of the tabulæ, as in some Tabulata. The walls are solid, compact, and united.

The corals contained in the family are all Silurian forms, so far as is known at present.

Thecia, Ed. & Haime. It is a most remarkable fact that this genus, the species of which have no true wall, but a dense cœnenchyma between septal prolongations or costæ, should here give the family name. *Thecia Swinderniana,* Goldfuss, sp., has been called *Agaricia, Porites, Astreopora,* and *Palæopora* by different authors, so that its classificatory position may well be a matter of doubt. It is not in the least allied to Columnariæ, which has solid walls, and which fulfils all the characteristics of the Thecidæ.

In *Thecia,* Ed. & H., there is a long visceral cavity surrounded by a dense tissue, as in *Millepora,* through which the septa, or rather the costa, run.

What is the structure of *Plasmopora* and *Propora* but that of *Thecia* slightly modified. The genus clearly must be associated with them amongst the Milleporidæ.

Columnaria is a fine form; the great septa (12 to 18) and tabulæ, with the compact walls, distinguish it at once. *Col. alveolata* is a Lower Silurian form, *C. Gothlandica* is Upper Silurian. It is a most important genus, and its affinities will be noticed.

The Favositidæ have a massive corallum without cœnenchyma, septa, and perforate walls; that is, there are openings which permit the visceral cavity of one corallite to communicate with that of another in several places. The following genera are included by MM. Milne-Edwards and Jules Haime:—*Favosites, Emmonsia, Michelinia, Rœmeria, Koninckia, Alveolites.*

Favosites is the typical genus. In some species the mural foramina are scanty in number, in others numerous; and they are even in relation with the angles of the wall, especially in *F. alveolaris.*

The earliest species of the genus are Lower Silurian, for instance:—*F. Gothlandica, F. multipora, F. aspera, F. Forbesi* (which ranges through to the Upper Silurian), and *F. fibrosa* (having the same vertical range, and is found as a Devonian fossil).

F. Hisingeri has the same range as *F. fibrosa. F. cristata* and *F. cervicornis* are the same, and the range is from the Upper Silurian of England to the Devonian of Russia.

The species which are Devonian, and do not range above or below, are:—*F. Goldfussi, F. basaltica, F. polymorpha, F. alveolaris, F. pediculata, F. Tchihatcheffi,* and *F. mammillaris.* The only known Carboniferous *Favosites* is *F. parasitica,* and it is a degenerate form.

F. Gothlandica has rounded processes encircling the mural pores, and the projections formed upon one fit against those of the neighbouring corallite. *F. multipora* has three vertical series of pores, and its walls are almost as perforate as some Alveoporæ.

The tabulæ are almost universally horizontal in the *Favosites,* but some are wavy in their course; and the septa are a series of vertical spines which vary in size according to the cycle, and are often referable to three cycles in six systems. In some there is a faint columellary swelling on the tabulæ.

A careful examination of the species proves that the earliest known forms are as highly developed as the Devonian, but that the species *parasitica* is dwarfed.

Emmonsia has imperfect tabulæ. The tabulæ are vesicular at the sides, or dissepimental, and they communicate more or less with each other.

Rœmeria has infundibuliform tabulæ, and the species is Devonian.

Koninckia is an Upper Cretaceous form; it has thin and nearly horizontal tabulæ, thin walls very much perforated, and six series of large spiny septa.

Michelinia has irregular and vesicular (dissepimental) tabulæ, and simple striæ for septa (Devonian and Carboniferous). The alliance of *Michelinia, Rœmeria,* and *Emmonsia* is very evident. Mr. Kent has written a most interesting description of *Favositipora* (Kent), Ann. & Mag. Nat. Hist. 1870, vol. vi. p. 384, which unites the Favositinæ and the Favositidæ.

Alveolites offers the same objection to being united to *Favosites* that *Cœnites* does to *Pocillopora*; in fact *Alveolites* is a *Cœnites* with perforated walls, and it is proposed to deal with both genera by disassociating them from their recognized families.

Syringopora I propose uniting with the Favositidæ, as it has tubular connexions between the visceral centres of the corallites, which are foreshadowed in *F. Gothlandica.*

After this analysis of the Tabulata, it is necessary to state the opinions of Prof. Agassiz respecting their Hydrozoan characteristics.

Prof. Agassiz (senior) writes as follows in the 'American Journal of Science and Arts,' 2nd series, vol. xxvi. p. 140, November 1858:—

"The animals of *Millepora* are Hydroid Acalephs and not polyps;" that is to say, they are Hydrozoa and not Actinozoa. The *résumé* of several letters to Dana is given at the same place. "I have seen," writes Agassiz, "in the Tortugas something very unexpected. *Millepora* is not an actinoid polyp but a genuine Hydroid, closely allied to *Hydractinia.* This seems to carry the whole group of Favositidæ over to the Acalephs, and displays a beautiful array of this class from the Silurian to this day."

Dana adds a note to this statement. "The drawings of Professor Agassiz which have been sent us for examination are so obviously Hydractinian in most of their characters that no one can question the relation. With regard to the reference of all the Favositidæ (a group including *Favosites, Fenestella, Pocillopora*, &c., as well as the minuter *Millepora, Chætetes*, &c.) to the Acaleph class, direct evidence is not yet complete, as the animal of the *Pocillopora* has not been figured by any author on zoophytes. From the specimens of the species of this genus which I procured in the Pacific, I never obtained a clear view of the polyps, and hence made no figure. The brief description on page 523 of my Report may be reasonably doubted until confirmed by new researches. The much larger cells in *Pocillopora, Favosites,* and *Fenestella* than in *Millepora,* and the frequently distinct rays in these cells, are the characters I had mentioned to Prof. Agassiz as suggesting a doubt as to their being Acalephs, and to this what follows above relates."

Agassiz observes, in a subsequent letter, after observing that the Sideroporæ obviously are polyps, "There are two types of radiating lamellæ which are not homologous. In true polyps (excluding Favositidæ as Hydroids) the lamellæ extend from the outer body-wall inward along the whole height of that wall, and the transverse partitions reach only from one lamella to the other, so that there is no continuity between them, while the radiating lamellæ are continuous from top to bottom in each cell. In Milleporidæ the partitions are transverse and continuous across the cells; so are they in *Pocillopora* and in all Tabulata and Rugosa; while the radiating lamellæ, where they exist, as in *Pocillopora* and many other Favositidæ, rise from these horizontal floors, and do not extend through the transverse partitions; indeed they are limited within the spaces of two successive floors, or to the upper surface of the last. A careful comparison of the corallum of *Millepora* and *Pocillopora* with that of *Hydractinia* has satisfied me that these radiating partitions of the Favositidæ, far from being productions of the body-wall, are foot-secretions, to be compared to the axis of the *Gordonia* corallum &c., and their seeming radiating lamellæ to the vertical groove or keel upon the surface of the latter, which, reduced to a horizontal projection, would also make the impression of radiating lamellæ in the foot of the polyp. If this be so, you see at once that apparent radiating lamellæ of the Favositidæ do no longer indicate an affinity with the true polyps, but simply a peculiar mode of growth of the corallum; and of these we have already several types, that of Actinoids, that of Alcyonoids, that of Bryozoa, that of *Millepora,* and other corallines, to which we now add that of Hydroids. Considering the subject in this light, is there any further objection to uniting all the Favositidæ with the Hydroids? *Sideropora* and *Alveopora* being of course removed from the Favositidæ. It is a point of great importance in a geological point of view, and for years I have been anticipating some such result, as you may see by comparing my remarks in the 'American Journal,' May 1854, p. 315. If all the Tabulata and Rugosa are Hydroids, as I believe them to be, the class of

Acalephs is no longer an exception to the simultaneous appearance of all the types of Radiata in the lowest fossiliferous formations, and the peculiar characters which these old Hydroid corals present appears in a new and very instructive aspect."

A. Agassiz includes the Tabulata amongst the Hydrozoa. He notices "that the absence of radiating partitions in the Tabulata seems to show without much doubt that their true place is among the Hydroids." It is true that Prof. Agassiz has not observed the Medusa-buds on the specimens he has figured, yet the Hydroid character of the animal and their similarity to *Halochœris*-like Hydroids is very striking (Havard Catalogue, 1865, p. 219).

Prof. Alexander Agassiz informs me that his father still holds these opinions, and that new researches have satisfied him about the correctness of the drawings which have been lately reproduced. "*Millepora* is not an actinoid polyp, but a *genuine* Hydroid, closely allied to *Hydractinia*."

This very strong expression of opinion is founded upon the appearance presented by the polyps of *Millepora alcicornis*, the drawing of which has been reproduced by A. Agassiz. Now the distinction between the Actinozoa and the Hydrozoa is well marked; in the first the generative apparatus is included in the gastric and perigastric cavities, and in the last the digestive and generative organs are perfectly apart. Every variety of tentacular and disk apparatus may exist in either, but the external development of the gemmules, ova, and embryonic forms must be recognized before any Cœlenterate animal can be associated with the Hydrozoa.

Here is the point at which Agassiz fails. His researches are only suggestive, until the generative organs are recognized on the protruded polypes of *Millepora*, and until the mesenterico-ovarian layers are proved not to exist within the calices. The external resemblance of the Millepore polypes to the sterile *Hydractinia* is evident.

The remarks upon Favositidæ, Sideroporæ, and other genera, made by Agassiz in consequence of the assumption that *Millepora* is Hydrozoan, are of doubtful value; and I must refer back to my analysis of the Tabulata to show how a confused classification between both classes imperils research. *Sideropora* is not a tabulate form even. A careful examination of *Columnaria* satisfies me that Agassiz's description of the lamellæ fails in that genus; and inasmuch as the wavy lines of *Gorgonia* and *Corallium* are connected with the water system of the species, they can have no possible relation with the radiate amellæ or groovings of the Milleporan calices. The homologues of the grooves are the depressions and irregular interstriated portions on top of the cœnenchyma between the calices in the Tabulata.

The perforate walls and the septa of the true Favositidæ seem to remove them from the range of the remarks of Agassiz, which may well deserve attention, so far as *Millepora* is concerned, for it is a genus with marked distinctions from all other corals.

It is not reasonable to include the Rugosa, because some of them have no tabulæ, and others have them so much like dissepiments, or associated with dissepiments, that we are impressed with the unimportance of the differentiations established by the presence of horizontal tabulæ.

It is most important that the minute structure of the Milleporidæ should be thoroughly investigated, and any report on the Palæozoic corals must be very incomplete without a detailed description of its study.

Section TABULATA.

Families.

With cœnenchyma	*Milleporidæ.*	Cœnenchyma cellular.
	Acroporidæ.	Cœnenchyma compact.
Without cœnenchyma ..	*Favositidæ.*	Walls perforated.
	Halysitidæ.	Walls imperforate.
	Alveolitidæ.	Septa tridentate.

Genera.

MILLEPORIDÆ	*Millepora**.
	Heliolites, Heliopora†, *Polytremacis.*
	Propora, Plasmopora, Thecia.
	Lyellia.
	Thecostegites.
	Axopora.
ACROPORIDÆ	*Acropora, Seriatopora, Pocillopora, Dendropora, Rhabdopora.*
FAVOSITIDÆ	*Favosites, Koninckia, Favositipora*, genus nov. (Kent).
	Michelinia, Rœmeria, Emmonsia.
	Syringopora.
	Aulopora.
HALYSITIDÆ	*Halysites.*
	Stylophyllum.
	Conostegites.
	Columnaria.
	Beaumontia.
ALVEOLITIDÆ	*Alveolites.*
	Cœnites.
Incertæ sedis	*Fistulipora.*
	Fletcheria.

ALCYONARIA.

Chætetes. *Monticulipora.* *Dania.* *Stellipora.* *Labechia.*

IV. The Rugosa.—MM. Milne-Edwards and Jules Haime observe (*op. cit.* vol. iii. p. 323), "that this division comprehends simple and compound corals, and that the septal apparatus never forms six distinct systems, and appears to be derived from four primitive elements. Sometimes this disposition is shown by the great development of four principal septa, or by the existence of four depressions which occupy the bottom of the calice and take on a cross-like look. In other instances there is observed only one of these depressions or excavations, or one large septum interferes with the regularly radiate and star-shape of the septal arrangement. Finally, there are instances where no traces of distinct groups or systems of septa can be recognized, and where the septa are represented by numerous striæ arising on the upper surface of the tabulæ or dissepiments near the calicular margin." They continue as follows:—"The corallites are always perfectly distinct amongst themselves, and are never united by independent cœnenchyma. The walls are in general very slightly developed. The visceral chamber is

* *Millepora* is a most aberrant genus if it is one of the Madreporaria Tabulata. I have not yet satisfied myself about the Hydroidean characteristics of its soft parts; but an examination of the cœnenchyma of a series of species throws great doubt upon the Madreporarian affinities.

† The relation of *Heliopora* to *Heliolites* is of the closest.

ordinarily occupied by a series of tabulæ or vesicular endotheca, and the endotheca often occupies the greater part of the corallum. The septal laminæ, although generally very incomplete, are never perforated or 'poutrellaire;' finally, their lateral faces are not furnished with synapticulæ, and are only rarely granular.

"The individual corallites increase by gemmation, and never by fissiparity. The buds are generally calicular, and this form of gemmation may continue in the same individual. In some cases the gemmation is lateral."

The originators of the "Rugosa" divide them into four families:—

1. Stauridæ.
2. Cyathoxonidæ.
3. Cyathophyllidæ.
4. Cystiphyllidæ.

In criticising this classification some definite plan must be adopted, which should refer to the philosophy of the classification of the Aporosa and Perforata. In fact the scheme of generic subdivision and differentiation adopted in the Neozoic corals can be made to apply to those of the Palæozoic age. Thus an essential distinction is made amongst the Neozoic corals by the simple or compound nature of the corallum. Simple Caryophyllinæ constitute a series of genera, and the compound forms are separated as Cœnocyathi. Now in the Palæozoic genus *Cyathophyllum*, MM. Milne-Edwards and Jules Haime admit, in direct opposition to the Neozoic scheme, both simple and compound forms. This, I think, is an error, but only an error of classification, for there can be no reasonable doubt of the intimate genealogical relation of the simple and compound genera of *Cyathophyllum*.

Families.*

1. STAURIDÆ.—Genera: *Stauria, Holocystis, Polycœlia, Metriophyllum, Conosmilia.*

Of these *Holocystis* is a Lower Greensand form, and *Conosmilia* is Australian and Tertiary.

MM. Milne-Edwards and Jules Haime place the Stauridæ first in their list of families; but it would have made the classification more simple if the second family took their place; and I propose to change the order of arrangement, but proceed at present in the recognized method.

There is a well-developed wall in the Stauridæ; the septa are continuous from the top to the bottom of the calice, and are eminently quaternary in their arrangement. The endotheca assumes the vesicular structure between the septa, and then crosses over in the form of horizontal tabulæ. The Stauridæ approach the Cyathophyllidæ more than the Cyathoxonidæ; and, indeed, the only essential distinction between the first two families is in the truly lamellar state of the septa in the first instance, and in the incomplete condition of them in the second. Nevertheless it should constitute a family distinction.

Two of the Stauridian genera are compound, and three are simple forms.

Stauria, which as yet has not been found in British strata, has neither columella nor costæ, whilst *Holocystis* has both of these structures. There is no reason why the last-named genus should not be the lineal descendant of the former. Both were probably shallow-water forms in the neighbourhood of reefs.

The simple forms *Conosmilia* and *Polycœlia* are closely allied, and the presence of the first in the Australian Tertiaries, and of the other in the Euro-

* See Hist. Nat. des Coralliaires, vol. iii. p. 325 *et seq.* (Milne-Edwards and Jules Haime).

pean Permian, is highly suggestive. The remaining form, *Metriophyllum*, offers a great difficulty, for if the received classification be adopted, the genus is very aberrant. Thus *Metriophyllum* has not four principal septa, but the septa are arranged in four groups, a gap or kind of septal fossula being between each group. The British Devonian species (*M. Battersbyi*, Ed. & H.) was founded upon a transverse section of a slab, and therefore the entire nature of the septa could hardly be determined. The question arises at once, what do those septal fossulæ mean? And another follows very naturally, are they in relation with the primary septa?

I think that they denote a difference in the physiology of the polype, for they would permit of a deeper development of the visceral cavity and an enlarged condition of the ovarian apparatus. Moreover, these fossulæ may have much to do with the growth of the coral in calibre and in septal number; and, furthermore, Lindström's admirably suggestive paper on the operculated structures, necessitates much attention being paid to them. Can there be any genealogical classification which will connect in one family such different forms as *Metriophyllum* and *Polycœlia*? I think not.

Eliminating, then, *Metriophyllum* from the Stauridæ, I propose to permit the genus to remain *per se* for the present.

2. Cyathoxonidæ.—Genera: *Cyathoxonia*, Palæozoic; *Haplophyllia* (Pourtales) and *Guynia* (Duncan), recent.

This group has no endotheca, and resembles the Turbinolidæ amongst the Neozoic corals, but it has the quaternary arrangement of the septa.

All the forms are simple. *Cyathoxonia* preceded the others, and all are closely allied. The foreshadowing of the Neozoic forms in the Palæozoic Cyathoxonidæ is evident enough.

Report on the Heat generated in the Blood during the process of Arterialization. By Arthur Gamgee, *M.D., F.R.S.E., Lecturer on Physiology in the Extra-Academical Medical School of Edinburgh.*

In a Report which was submitted to the British Association in Liverpool last year*, I very shortly alluded to the objects which I had in view in commencing an investigation on the very obscure subject of the heat generated during the arterialization of blood.

I pointed out that two methods of research suggested themselves as likely to elicit facts which would lead to a solution of the problem, and I stated that both these methods had been employed by previous observers.

The first method, which would at first sight appear likely to furnish us with most important data, consists in ascertaining the temperature of the blood in the right and left ventricles of the heart of living animals. If our methods of experimenting were free from the great fallacies which are introduced when we are compelled to interfere, in a serious manner, with the central organ of the circulation, and if it resulted that the left side of the heart contained blood warmer than that of the right side, we should be driven to the conclusion either that during the process of absorption and combination of the oxygen of the air a very perceptible evolution of heat had oc-

* Report of the Liverpool Meeting, p. 228.

curred, or that within the pulmonary vessels considerable oxidation processes of the blood contained in them had taken place. If, on the other hand, the temperature of the left side were the same as that of the right side, or lower, the question would still remain an open one; for heat might be evolved in the lungs, and yet the quantity might be insufficient to counterbalance the loss of heat due to the evolution of large quantities of watery vapour, of carbonic acid, and to the heating of the air which we daily inspire.

The first method, or that which consists in ascertaining the temperature of the two sides of the heart, need scarcely be touched upon at present; and I shall merely confine myself to the statement that, in the hands of the most experienced and reliable physiologists, and specially in those of Professor Claude Bernard, it has led to the curious result that the blood which reaches the left ventricle is colder than that which leaves the right. This result would, at first sight, appear to prove that if any heat be evolved in the lungs, its amount is not sufficient to compensate the losses to which I have already alluded, and rendered it absolutely essential that fresh experiments should be conducted by a second method, which consists in ascertaining whether, when venous blood removed from the body is agitated with oxygen or atmospheric air, any changes occur in its temperature.

The first step in the inquiry consisted in ascertaining the specific heat of blood, for none of the experiments previously made had led to trustworthy results. Dr. Crawford had, in the last century, advanced a theory of animal heat which was based upon an assumed difference in the specific heat of arterial and venous blood: he supposed that the former possessed a very high, and the latter a comparatively low specific heat; so that in becoming arterialized in the lungs, the heat resulting from the condensation, solution, and probable chemical combination of oxygen with the blood became latent, being, however, evolved as the blood circulated through the body, when, becoming venous, it acquired a continually diminishing specific heat. Dr. John Davy, in his 'Researches, Physiological and Anatomical,' vol. i. p. 141, in a chapter entitled "On the Capacities of Venous and Arterial Blood for Heat," described experiments which contradicted the hypothesis of Crawford as to the difference in the specific heat of the two varieties of blood, although the extraordinary discrepancies between different experiments rendered it impossible that any calculations could be based upon Dr. Davy's results. In his experiments, Dr. Davy made use of defibrinated blood, employing for the determination of specific heat the methods of mixture and rate of cooling.

In the experiments which I performed last year, and which are published in the last volume of the Reports of the British Association, I made use of the method of mixture, taking care to adopt all the precautions which modern experience has suggested. Making use of the perfectly fresh blood of the ox, which was sometimes venous, sometimes arterial, I obtained remarkably concordant results, the mean of which gave 1·02 as the coefficient of the specific heat of blood. Having made this determination, I could pass to the experiments intended to determine whether, in being arterialized, blood which is perfectly venous becomes hotter.

As a preface to my own researches on this subject, it is incumbent upon me to allude to all the observations which have been made on this subject. In the second volume of Dr. Davy's 'Researches, Physiological and Anatomical,' at p. 168 a section is devoted to the following question:—"*When oxygen is absorbed by the blood, is there any production of heat?*"

"To endeavour to determine this point," says Dr. Davy, "of so much interest in connexion with the theory of animal heat, a very thin vial, of the

capacity of eight liquid ounces, was selected and carefully enveloped in bad conducting substances, viz. several folds of flannel, of fine oiled paper, and of oiled cloth. Thus prepared, and a perforated cork being provided holding a delicate thermometer, 2 cubic inches of mercury were introduced, and immediately after it was filled with venous blood kept liquid as before described. The vial was now corked and shaken; the thermometer included was stationary at 45°. After five minutes that it was so stationary the thermometer was withdrawn; the vial, closed by another cork, was transferred to a mercurial bath, and $1\frac{1}{2}$ cubic inch of oxygen was introduced. The common cork was returned, and the vial was well agitated for about a minute: the thermometer was now introduced; it rose immediately to 46°, and, continuing the agitation, it rose further to 46°·5, very nearly to 47°. This experiment was made on the 12th of February, 1838, on the blood of the sheep. On the following day a similar experiment was made on the venous blood of man. The vial was filled with 11 cubic inches of this blood, its fibrine broken up in the usual manner, and with 3 cubic inches of mercury; the temperature of the blood and mercury was 42°·5, and the temperature was the same after the introduction of 3 cubic inches of oxygen. The temperature of the room being 47°, a fire having shortly before been lit, the vial was taken to an adjoining passage, where the temperature of the air was 39°. Here the vial was well agitated, held in the hand with thick gloves on as an additional protection; after about three quarters of a minute the thermometer in the vial had risen a degree, viz. to 43°·5." Dr. Davy relates two other experiments, of which the first was performed on the venous blood taken from the jugular vein of a sheep, the second on arterial blood. The three experiments with venous blood showed that when agitated with mercury and air for the space of a minute, venous blood was heated to the extent of 1° Fahr., whilst the arterial blood was heated only half a degree.

Dr. Davy quotes Sir Charles Scudamore, who, in his 'Essay on the Blood,' at p. 59, states that venous blood cools much more slowly in oxygen gas than in atmospheric air; that the same blood divided into two cupping-glasses, "after an interval of eight minutes from the beginning of the experiment," exhibited a difference of 8°,—that exposed to oxygen being 85°, that to atmospheric air 77°.

H. Nasse, in his article on Animal Heat in the fourth volume of Wagner's 'Handwörterbuch der Physiologie' (1842), quotes Marchand to the effect that when oxygen is shaken with blood the latter is heated.

In a paper entitled "On the Relative Temperature of Arterial and Venous Blood," Mr. W. B. Savory, having described at considerable length observations on the temperature of the two sides of the heart, describes others performed with a view to check the accuracy of the experiments of Dr. John Davy, and states the conclusions to which he was led by his own experiments, viz.:—1st, that when venous blood is treated, as was done by Dr. Davy in his experiments, with oxygen, its temperature was usually raised from 1° to $1\frac{1}{2}$° or 2°; 2ndly, that when venous blood was treated in a similar manner with hydrogen or carbonic acid, its temperature was as frequently raised, and generally to the same extent; 3rdly, that similar experiments upon arterial blood usually yielded the same results; 4thly, that in all cases the increase of temperature seemed to be the result of the agitation. In concluding his paper, Mr. Savory remarked, "At present there is no evidence upon which we can safely venture further into this inquiry. If, as I conclude from my experiments, arterial blood is warmer than venous, the increase of temperature must occur in the lungs as a result of those changes

which the blood there undergoes. Of the nature of those changes, little or nothing is known."

In my early researches, conducted during the months of May and June 1869, I had attempted to determine, by means of comparatively simple contrivances, whether any heat was evolved during arterialization, making use of delicate thermometers. At first I used a glass bottle furnished with a tubulature, near the bottom in which a cork, perforated and furnished with a glass tube closed by india-rubber tubing and a clip, was inserted. The neck of the bottle was furnished with a cork perforated in two places; through one of the perforations a delicate Centigrade thermometer passed into the centre of the flask, whilst into the other was inserted a bent glass tube through which gas might be introduced into the apparatus. The bottle which I have described was filled with venous blood, both the tubes communicating with its interior being closed. It was then maintained at a temperature varying between 30° and 35° C. for many hours, until it had assumed the characteristic cherry-red coloration which indicates the complete removal of the loosely combined oxygen of the blood. The apparatus having been allowed to cool, it was invested with a jacket of felt. An india-rubber tube was made to connect the upper glass tube with a hydrogen gasometer, whilst the lower tube being opened, the hydrogen expelled any required quantity of blood. The apparatus was then shaken and the temperature determined. Then by a repetition of the process (followed in the introduction of hydrogen) pure oxygen gas was made to displace more of the blood, and the process of shaking repeated as before. The results of such experiments were eminently unsatisfactory, varying obviously with the amount of mechanical work which was formed by the experiments, and which yet did not admit of exact determination.

In some experiments I observed a heating which amounted to 0°·3 C.; in other cases the difference in the readings, before the introduction of oxygen and after it, seemed to point to a cooling instead of to a heating. To give an idea of the indefinite and perplexing results which I obtained, I shall cite the details of an experiment performed on the 23rd of June, 1870, by Professor Tait and myself, the apparatus used being a tin vessel resembling in principle the one of glass which I have already described. This vessel was covered with felt, and, when shaken, it was held by means of a very strong iron clamp. Having been filled with sheep's blood, it was placed in an air-oven and maintained for a period of twelve hours at a temperature which oscillated between 100° and 110° Fahr. It was afterwards placed in the room in which my experiments were carried on; but in order to make it cool more rapidly, its felt covering was taken off, and it was placed in water at a temperature of 15° C. It was dried, again covered with felt, and fixed in its clamp. Hydrogen was then made to expel 4·5 cubic inches of blood, which was found by spectroscopic examination to exhibit the single band of reduced hæmoglobin; after shaking the blood and hydrogen in the apparatus, its temperature was found to be 17°·8 C., then 18° C., the temperature of the air being 20°·4 C. 10 cubic inches of blood were then drawn off and replaced by oxygen, which was brought in contact with the blood by shaking; the temperature rose to 18°·1 C.: more oxygen was introduced and the shaking repeated, the temperature rising to 18°·25, 18°·4, 18°·5, 18°·6, 18°·6, 18°·55, 18°·7, 18°·75, 18°·77. At the conclusion of the experiment the quantity of blood which had been arterialized was found to be 360 cubic centims. This experiment merely gave one of many results; for as long as I followed this method I was quite unable twice to determine the same

amount of heat as the result of oxygenation of the blood. The amount of heating in a given time depended upon several important factors, as the difference between the temperature of the blood in the experimental vessel and that of the surrounding air, upon the amount of blood contained in the apparatus, and the space through which the vessel was moved during its agitation, no less than upon the number of the agitations.

To describe, or even to give the results of a series of experiments so eminently unsatisfactory, would be a mere waste of time; it will be sufficient for me to state, however, that I clearly came to the conclusion that, like those who had preceded me, I had obtained no positive proof of the heating of blood when it absorbs oxygen, there having been as great a heating when water as when blood was experimented upon.

In commencing new experiments this year, I did so with the conviction that, in order to obtain results of any value, my apparatus should be so constructed and my experiments so conducted as to preclude the possibility of any appreciable rise in temperature resulting from the mechanical work of shaking. Then I decided upon discarding thermometers, and making use of thermo-electric junctions of great delicacy.

The galvanometer employed in the research was one resembling one of Sir Wm. Thomson's older forms, constructed especially for Professor Tait, every possible precaution having been taken to avoid a trace of iron in the coils and framework. The wire was drawn through agate plates from electrolytic copper, covered with white silk and formed into four coils, each adjusted to produce the maximum effect with the least resistance, those parts of the coils nearest the magnets being made of finer wire. The astatic system vibrated under the earth's force once in eight seconds; but as this was much too delicate for my purpose, I placed near the instrument a bar-magnet, which reduced the period of vibration to $3^{s}\cdot4$.

The thermo-electric junctions which I employed were made by twisting very thin iron and copper wire together, the free ends of the copper wires being immersed into the mercury pools of a very simple form of commutator placed in the circuit, which enabled me, with the greatest ease, to reverse the current flowing along the wires.

The apparatus actually employed in my experiments consisted of an upper glass vessel, which I may call the blood reservoir, to which was connected a lower vessel, also of glass, and in which the blood, which was the subject of experiment, could be brought in contact with the gases which were intended to act upon it.

The upper vessel was a glass bulb of a pyriform shape, and had a capacity of about 150 cubic centimetres. Above and below it was drawn out, so as to present two tubes, the upper of which was bent at right angles and furnished with a piece of india-rubber tubing, which admitted of being closed by a clamp, whilst the lower was furnished with a very accurately ground stopcock. In the side of the bulb was a round tubulature, which could be closed with a cork, through which passed a thermo-electric junction. The lower, or mixing-vessel, was cylindrical in shape, and possessed four apertures. The upper one was closed by a cork, bored so as to allow of the passage of a glass tube, attached above by means of an elastic tube to the stopcock of upper vessel or reservoir, and made of such a length as to reach to the bottom of the mixing-vessel. Near the upper aperture was a second lateral one, into which a glass tube had been fused. This glass tube could be connected, by means of a metallic tube and stopcocks, either with a Sprengel mercurial aspirator or with an oxygen or hydrogen gasometer. A third lateral aperture was

closed with a cork, perforated (like the one which closed the upper vessel) by a second thermal junction. A fourth aperture in the mixing-vessel, closed by a stopcock, enabled it to be emptied.

In determining with such an apparatus whether heat is generated when venous blood becomes arterial, the upper vessel is disconnected from the lower at a point below the glass stopcock previously described; it is completely filled with water, and then the water is displaced by a stream of pure hydrogen gas admitted through the upper tube.

The lower glass tube is then connected with the vessel which contains the blood to be experimented upon. The upper tube, through which hydrogen had been admitted, is now connected to the Sprengel pump, which rapidly sucks the blood into the vessel, without the slightest possibility of its coming in contact with oxygen. The upper vessel is either partially or completely filled with blood, but it always is ultimately left in connexion with a hydrogen gasometer.

The mixing-vessel (the lowest aperture of which has been closed by india-rubber tubing and clip) is now connected to the Sprengel pump, and a vacuum is formed into which hydrogen is allowed freely to flow. The vacuum is renewed three or four times consecutively, hydrogen being allowed to flow into the apparatus each time. The object of this is to exclude traces from the lower vessel of atmospheric oxygen.

The stopcock which connects the upper and lower vessels is opened, and venous blood is allowed to flow into the lower vessel. In actual work both the upper and lower vessels are thickly covered with wadding. The upper one is firmly fixed in a clamp, and constitutes a reservoir, which, except when the atmospheric changes in temperature are abnormally sudden, maintains during limited periods of time a constant temperature. The lower tube being connected to the stopcock of the upper by means of a flexible india-rubber tube, admits of being completely tilted, or, if necessary, shaken.

As soon as the lower vessel contains the blood to be experimented upon, the thermal junctions are brought in connexion with the galvanometer. The amount of deviation on the graduated scale, and the direction of the deviation, at once tells the experimenter whether the upper or the lower junction be the hotter. The lower vessel is thoroughly shaken, then, after some time, the temperature of its contents is determined by reading on the scale placed in front of the galvanometer. The tube and its contents are then repeatedly tilted, a reading of the galvanometer being taken after each set of five tilts. After a certain time the lower vessel has assumed a constant temperature, and readings, at the interval of two or three minutes, show no perceptible change. I may remark that the galvanometer which, through the kindness of Prof. Tait, was placed at my disposal was so set that in my various experiments one division of the divided scale corresponded to the 100th or the 120th of a degree Cent. The first observations made with my apparatus were intended to determine whether such an amount of agitation as would be required to communicate a thoroughly arterial colour to perfectly venous blood would heat the fluid to a perceptible extent, in consequence of the mechanical work expended in the agitation.

In preliminary experiments I found that venous blood assumed a beautiful arterial hue, when it was mixed with oxygen contained in the mixing-vessel, by successively tilting the tube twenty times. In each tilt the tube containing blood and oxygen was completely reversed. In other preliminary experiments I found that when the tube contained thoroughly arterialized blood or water, the process of tilting had no influence on the

temperature of the contained fluid. It was, therefore, obvious that any heating which might occur in the process of tilting or shaking in subsequent experiments could not be referred to the mechanical work expended in the tube and its contents.

My next experiments consisted in determining whether, when agitated with a neutral gas, as, for example, hydrogen, any material change in the temperature of the blood occurred; they led to the result that when agitated with hydrogen gas no heating of the blood results, it being always remembered that the mechanical agitation to which the blood and the neutral gas were subjected was the same as in my experiments with blood and oxygen.

In my systematic experiments on the heat generated during the process of arterialization, the following observations were always made:—

1. The temperature of the lower as contrasted with the upper vessel was determined after the latter had been exhausted.
2. The temperature-observations were repeated after shaking with hydrogen.
3. After the renewal of a vacuum.
4. After admission of oxygen in the mixing-vessel.
5. After oxygen had been thoroughly shaken with the blood.

The results of my experiments on very numerous samples of venous blood have led to the conclusion that whilst, as I have previously mentioned, no heat is evolved on agitating blood with hydrogen, *there is*, on agitation with oxygen, *always a slight evolution of heat.*

To determine the exact heating, when venous blood of varying gaseous composition is arterialized, appears to be most desirable. We should especially attempt to determine the heating observed when the average venous blood contained in the right ventricle and directly drawn from it is arterialized. The first and most important datum to be ascertained appeared to me, however, to be the heating which takes place when blood which has been thoroughly reduced, *i. e.* which contains no loosely combined oxygen and exhibits Stokes's spectrum, is completely arterialized.

From five sets of experiments on the heat developed during the arterialization of perfectly reduced blood, I arrived at the conclusion that the mean rise of temperature during the absorption of oxygen amounted to 0°·0976 C. The maximum heating found was 0°·111 C., and the minimum 0°·083 C.

The research, of which the above are the results, was conducted in the Physical Laboratory of the University of Edinburgh; and I have to express my thanks to Professor Tait for the uniform kindness with which he helped me by advice, assistance, and apparatus in ascertaining the facts which are recorded in this Report. I intend to extend these researches very greatly. It is most desirable that in future experiments venous blood of known composition be employed, and that the amount of oxygen absorbed and CO_2 evolved be ascertained after each experiment. I propose likewise to increase the period during which the blood is agitated, making use of an arrangement whereby the mechanical work performed in the agitation may be precisely determined.

Report of the Committee appointed to consider the subject of Physiological Experimentation.

A COMMITTEE, consisting of ten individuals, having been appointed at the last Meeting of the British Association, held at Liverpool, to consider the subject of Physiological Experimentation, in accordance with a Resolution of the General Committee hereto annexed, the following Report was drawn up and signed by seven members of the Committee.

Report.

i. No experiment which can be performed under the influence of an anæsthetic ought to be done without it.

ii. No painful experiment is justifiable for the mere purpose of illustrating a law or fact already demonstrated; in other words, experimentation without the employment of anæsthetics is not a fitting exhibition for teaching purposes.

iii. Whenever, for the investigation of new truth, it is necessary to make a painful experiment, every effort should be made to ensure success, in order that the suffering inflicted may not be wasted. For this reason, no painful experiment ought to be performed by an unskilled person with insufficient instruments and assistance, or in places not suitable to the purpose, that is to say, anywhere except in physiological and pathological laboratories, under proper regulations.

iv. In the scientific preparation for veterinary practice, operations ought not to be performed upon living animals for the mere purpose of obtaining greater operative dexterity.

Signed by:—M. A. LAWSON, Oxford. G. M. HUMPHRY, Cambridge.
JOHN H. BALFOUR, ARTHUR GAMGEE, } Edinburgh.
WILLIAM FLOWER, Royal College of Surgeons, London.
J. BURDON SANDERSON, London.
GEORGE ROLLESTON, *Secretary*, Oxford.

Resolutions referred to in the Report.

That the Committee of Section D (Biology) be requested to draw up a statement of their views upon Physiological Experiments in their various bearings, and that this document be circulated among the Members of the Association.

That the said Committee be further requested to consider from time to time whether any steps can be taken by them, or by the Association, which will tend to reduce to its minimum the suffering entailed by legitimate physiological inquiries; or any which will have the effect of employing the influence of this Association in the discouragement of experiments which are not clearly legitimate on live animals.

The following resolution, subsequently passed by the Committee of Section D (Biology), was adopted by the General Committee:—

"That the following gentlemen be appointed a Committee for the purpose of carrying out the suggestion on the question of Physiological Experiments made by the General Committee,—Professor Rolleston, Professor Lawson, Professor Balfour, Dr. Gamgee, Professor M. Foster, Professor Humphry, Professor W. H. Flower, Professor Sanderson, Professor Macalister, and Professor Redfern; that Professor Rolleston be the Secretary, and that they be requested to report to the General Committee."

Report on the Physiological Action of Organic Chemical Compounds. *By* BENJAMIN WARD RICHARDSON, *M.A., M.D., F.R.S.*

THE plan I have heretofore followed, of passing under review the practical results of the labours chronicled in previous Reports, cannot be carried out this year. The review itself would now become so comprehensive that it would occupy all the time allowed for the reading of the Report to the exclusion of the new matter to be brought forward. I shall therefore proceed at once to the description of new research.

CHLORAL HYDRATE.

It is two years since the substance called chloral hydrate (the physiological properties of which had been previously discovered by Liebreich) was introduced into this country at the Norwich Meeting of this Association. During the first year of the employment of chloral hydrate the enthusiasm connected with the learning of its value prevented, in some degree, all fair criticism as to its real values and dangers. The year immediately past has afforded time for calmer and more judicial observation, greatly, as I think, to the advantage of the public, since it has given to the professors of medical art the opportunity of learning that the new agent placed in their hands, blessing as it is to humanity, is not an unalloyed blessing, but one that has engendered a new and injurious habit of narcotic luxury, and has added another cause to the preventible causes of the mortality of the nation.

Recognizing these truths, I have felt it a duty to devote some part of the labours of this Report to the elucidation of questions which have become of public, not less than of scientific importance, and to these I would now ask attention.

1. I have endeavoured to ascertain what is a dangerous and what a fatal dose of chloral hydrate. The conclusion at which I have been able first to arrive on this point is, that the maximum quantity of the hydrate that can be borne, at one dose, bears some proportion to the weight of the animal subjected to its influence. The rule, however, does not extend equally to animals of any and every class. The proportion is practically the same in the same classes, but there is no actual universality of rule. A mouse weighing from three-quarters of an ounce to an ounce will be put to sleep by one quarter of a grain of the hydrate, and will be killed by a grain. A pigeon weighing twelve ounces will be put to sleep by two grains of the hydrate, and will be killed by five grains. A guineapig weighing sixteen ounces will be put by two grains into deep sleep, and by five grains into fatal sleep. A rabbit weighing eighty-eight ounces will be thrown by thirty grains into deep sleep, and by sixty grains into fatal sleep.

The human subject, weighing from one hundred and twenty to one hundred and forty pounds, will be made by ninety grains to pass into deep sleep, and by one hundred and forty grains into a sleep that will be dangerous.

From the effects produced on a man who had of his own accord taken a hundred and twenty grains of the hydrate, and who seemed at one period to be passing into death, I was led to infer that in the human subject one hundred and forty grains should be accepted as dangerous, and one hundred and eighty as a fatal dose. Evidence has, however, recently been brought before me which leads me to think that, although eighty grains would in most instances prove fatal, it could, under very favourable circumstances, be recovered from.

Dr. Hills, of the Thorpe Asylum, Norwich, has, for example, favoured me with the facts of an instance in which a suicidal woman took no less than *four hundred and seventy-two grains* of the hydrate dissolved in sixteen ounces of water, and actually did not die for thirty-three hours. Such a fact, ably observed as it was, is startling; but it does not, I think, militate against the rule that one hundred and forty grains is the maximum quantity that should, under any circumstances, be administered to the human subject.

2. A second point to which my attention has been directed is, what quantity of hydrate of chloral can be taken with safety at given intervals for a given period of time, say of twenty-four hours. To arrive at some fair conclusion on this subject, I calculated from a series of experiments the time required for the development of symptoms from different doses of the hydrate, the full period of the symptoms, and the time when they had entirely passed away. Great difficulties attend this line of investigation; but I may state, as a near approximation to the truth, that an adult person who has taken chloral in sufficient quantity to be influenced by it, disposes of it at the rate of about seven grains per hour. In repeated doses, the hydrate of chloral might therefore be given at the rate of twelve grains every two hours for twenty-four hours, with less danger than would occur from giving twelve times twelve (144) grains at once; but I do not think that amount ought, except in the extremest emergencies, to be exceeded even in divided quantities.

3. A third point to which I have paid attention is, the means to be adopted in any case when, from accident or other cause, a large and fatal dose of chloral hydrate has been administered. I can speak here with precision. It should be remembered that this hydrate, from its great solubility, is rapidly diffused through all the organism. It is in vain, consequently, to attempt its removal by any extreme measures after it has fairly taken effect. In other words, the animal or person under chloral, like an animal or person in a fever, must go through a distinct series of stages on the way to recovery or death; and these stages will be long or short, slightly dangerous or intensely dangerous, all but fatal or actually fatal, according to the conditions by which the animal is surrounded. One of the first and marked effects of the chloral is reduction of the animal temperature; and when an animal is deeply under the influence of the agent, in the fourth degree of narcotism of Dr. Snow, the temperature of its body, unless the external warmth be carefully sustained, will quickly descend seven and even eight degrees below the natural standard. Such reduction of temperature is itself a source of danger; it allows condensation of fluid on the bronchial pulmonary surface, and so induces apnœa, and it indicates a period when the convulsion of cold (a convulsion which sharply precedes death) is at hand.

I offer these explanations in order to indicate the first favourable condition for the recovery of an animal or man from the effects of an extreme dose of chloral hydrate. It is essential that the body of the animal be kept warm, and not merely so, but that the air inspired by the animal be of high temperature. The first effort to recovery, in short, should consist in placing the animal in a warm air. This fact is perfectly illustrated by experiment on the inferior animals. In the pigeon an air of 95° Fahr. is most favourable, in the rabbit an air at 105° to 110°, in the dog the same. In man the air to be breathed should be raised and sustained at 90° Fahr. at least*.

* I have no doubt it will be found, as the chronicle of deaths from chloral hydrate increases, that the mortality from the agent will be greatest when the thermometrical readings are the lowest, and *vice versâ*.

The next thing to be remembered in the recovery of persons under the fatal influence of chloral hydrate is to sustain the body by food. I find that under even deep sleep from the narcotic, although the process of waste is less than is common under natural conditions of rest, there is still a very considerable waste in progress, which, if not made up, is against recovery. I find also that the digestive and assimilating powers, though impaired during sleep from chloral, are not arrested, but may be called into fair action with so much advantage, that if two animals be cast into deep sleep by an excessive quantity of the narcotic, and one be left without food and the other be artificially fed on warm food, one fourth of the chance of recovery is given to the animal that is supplied with food. In the human subject warm milk, to which a little lime-water has been added, is the best food. Milk is very easily administered mechanically, and it should be administered in the proportion of half a pint every two hours*.

4. The fourth point to remember is to sustain the breathing; in the inferior animals the question of life or death can be made to turn on this pivot. But the artificial respiration must be carried out with great gentleness; it must not be done by vehement movements of the body or compressions of the chest, but by the simple process of inflating the lungs by means of small bellows, through the nostrils. I have devised, in the course of the researches conducted chiefly for the Association, various instruments for artificial respiration, viz. a small double-acting bellows, a small syringe, and a double-acting india-rubber pocket-bellows; but I have lately made an observation which leads to a simpler method still, *i. e.* I merely attach to a single hand-bellows a nostril-tube, and gently inflate the lungs, letting the elasticity of the chest-wall do the work of expiration. A little valve near to the nostril-tube effectually stops all back currents from the lungs into the bellows. For the human subject, five charges of air from the bellows should be given at intervals of five seconds apart†.

There is another subject of public interest connected with the employment of chloral hydrate. I refer to the increasing habitual use of it as a narcotic. As there are alcoholic intemperants and opium-eaters, so now there are those who, beginning to take chloral hydrate to relieve pain or to procure sleep, get into the fixed habit of taking it several times daily and in full doses. I would state from this public place, as earnestly and as forcibly as I can, that this growing practice is alike injurious to the mental, the moral, and the purely physical organization, and that the confirmed habit of taking chloral hydrate leads inevitably to confirmed disease. The digestion gets impaired; natural tendency to sleep and natural sleep are impaired; the blood is changed in quality, its plastic properties and its capacity for oxidation being reduced; the secretions are depraved; and, the nervous system losing its regulating, controlling power, the muscles become unsteady, the heart irregular and intermittent, and the mind uncertain and irritable. To crown the mischief, in not a few cases already the habitual dose has been the last, involuntary or rather unintentional suicide closing the scene.

I press these facts on public notice not a moment too soon, and I add to them the facts, that hydrate of chloral is purely and absolutely a medicine, and that whenever its administration is not guided by medical science and experience, it ceases to be a boon, and becomes a curse to mankind.

* This question of feeding is applicable to all forms of accidental narcotic poisoning. In every such case the poisoning is a distinct process, and the recovery turns largely on the sustainment of the animal force by supply of food and of external warmth.

† Dr. Richardson exhibited the different instruments described.

Anhydrous Chloral.

The hydrate of chloral, of which I have treated above, is made from another substance, called anhydrous chloral, by the addition to the latter of a certain proportion of simple water. Anhydrous chloral was discovered by Liebig in 1832, and is formed by the process of passing chlorine through absolute alcohol. It is a colourless oily fluid, of specific gravity 1502, at 64° Fahr. It boils at 93° Cent. (199° Fahr.); its composition is C_2HCl_3O, and its vapour-density, taking hydrogen as unity, is 73. It dissolves in ether, alcohol, and hydride of amyl.

The vapour of anhydrous chloral is irritating and painful to an extreme degree when it is inhaled, and the substance has consequently not attracted attention as a subject for physiological study. Having, however, a pure specimen of it prepared by Dr. Versmann, I thought it was worth while to make a research with it. The results have proved worthy of the trouble; in fact I have rarely derived from so simple an investigation so rich a practical result. It would be inferred *à priori* that anhydrous chloral in the liquid state would be, like its vapour, a powerful irritant to the skin and mucous membrane. I soon found, however, that this was not the fact, that I could apply the fluid freely to my own skin and to the tongue without injury, and that the caustic action is extremely mild, even when the substance is applied to a moist surface. If a quarter grain of it (anhydrous chloral) be placed upon the skin of the frog in a dry atmosphere, there is a rather quick absorption, followed by the formation of a white film of the hydrate of chloral beneath the skin, which film soon disappears by absorption, the symptoms following the absorption being the specific narcotic symptoms of chloral hydrate. The animal soon falls into a deep sleep with complete muscular exhaustion.

If in higher animals, birds and rabbits, anhydrous chloral be injected subcutaneously, the same phenomena are indicated, the quantities for producing the specific effects being the same as are required for the hydrate.

It is clear from these observations that anhydrous chloral, when brought into contact with the exposed surfaces of the body, abstracts water from the part with which it is in contact, becomes converted into the hydrate, and is directly absorbed into the body, producing the same symptoms as the prepared hydrate produces when it is introduced into the organism.

As anhydrous chloral is soluble in amyl hydride, ether, and many other volatile fluids, I tried whether any of it could be carried over with the vapour of amyl hydride, and whether, if it were administered in this way, it would produce prolonged narcotism by being transformed into the hydrate in the lungs and taken up into the blood.

The result of the experiment was to show that in frogs, guineapigs, and pigeons general narcotism can be so induced, and that the narcotism is prolonged far beyond what follows from the simple inhalation of amyl hydride. But I observed that when the solution used contained so little as twenty minims of anhydrous chloral to an ounce of the hydride, the vapour given off was irritating to breathe; and when I breathed it myself I found it caused dryness of the throat and a sense of constriction, which lasted several minutes. A weaker solution than that named is too slow in its action, and I therefore can hardly at this moment recommend that anhydrous chloral should be administered by inhalation. It is possible, nevertheless, that in course of time the agent may be found serviceable when administered in the manner described. It is probable that much smaller quantities, administered for a much

longer time, would be serviceable in sustaining a slight narcotism. It is probable that in some chronic diseases of the throat or bronchial passages, where the effect of a local narcotic would be desirable, this mode of practice may find favour from its success. Again, it may be that in disease of the lungs themselves, where there is loss of structure (cavity), anhydrous chloral may be inhaled in minute quantities with advantage. I name these points in order to call the attention of fellow physicians to the mode of administration I have ventured to suggest.

Connected also with anhydrous chloral is another reasonable suggestion; I mean the plan of applying the agent as a narcotic caustic to unnatural growths and ulcerating fungoid surfaces. I find that by applying the fluid to my arm freely there is destruction of the epidermis (scarf skin), so that without any pain the epidermis peels off, almost dry, at the point where the fluid has been placed; and that when on this exposed surface some of the fluid is applied, the true skin is in turn affected, so that in a day or two what the ancients called an issue may be developed, the tissues destroyed coming away in the form of scales. The surgeon will at once see the practical utility of an agent possessing these properties, and he may in some instances subcutaneously inject the fluid if the outward employment of it be too slow.

It is a very curious experiment to subject freshly drawn blood to anhydrous chloral, and to observe microscopically the changes that ensue. The action of the chloral is to extract water both from the liquor sanguinis and the corpuscles, and to form crystalline chloral hydrate. Into this formation the shrinking corpuscles sink, while the fibrine remains free from precipitation; but if water be added, so as to dissolve and remove the hydrate that has been formed, the corpuscles are to some extent restored, and the fibrine coagulates and separates in the usual way.

Metachloral.

Under favouring conditions anhydrous chloral is converted into an insoluble substance, to which the name of "metachloral" has been applied. The change sometimes occurs spontaneously, as it has done in a specimen now on the table; but it is always effected when chloral is brought into contact with sulphuric acid. Dr. Versmann has made for me some beautiful specimens of metachloral by this last-named process.

Metachloral is a white substance, easily reducible into a fine powder, but insoluble in water and in alcohol. It is isomeric with chloral itself, being merely different in respect to physical condition. When it is treated with an alkali it yields, as chloral does, an alkaline formate and chloroform. These facts led me to ask whether, in the animal body, metachloral would undergo decomposition and produce specific narcotic effects; and here, again, a series of results were obtained of great interest. Administered to birds in the form of pilule, and to other animals either in the same form or in suspension in gum emulsion, the metachloral, so insoluble in water, is found to undergo solution in the animal secretions, and to produce the same narcotic effects as the chloral hydrate, viz. narcotism, muscular prostration, and decrease of animal temperature.

In the pigeon from ten to fifteen grains are sufficient to take full effect. The animal in the course of an hour becomes drowsy, and in an hour and a half is in a perfect sleep, from which, nevertheless, it may be roused, to fall back again into sleep with great rapidity: the sleep lasts from three to four

hours. The temperature of the body undergoes considerable change, falling, in the pigeon, full five degrees Fahrenheit, and remaining so reduced that a period of eight and even nine hours is required for its complete restoration to the natural standard. On frogs the effect of metachloral is equally marked. A frog weighing ten drachms is fairly narcotized in thirty minutes by a dose of a quarter of a grain, the insensibility continuing many hours and closely simulating death. During the period of deep insensibility the muscles remain in the most extreme state of flaccidity, but do not fail to respond to the galvanic stimulus.

To rabbits comparatively larger doses of metachloral may be administered by the mouth without exciting any effect whatever. To a large rabbit weighing eight pounds, ten grains may be given with absolute freedom from symptoms of narcotism; but when the dose is increased to twenty grains a very distinct effect is produced. About one hour following upon the administration the animal sinks into sleep precisely as if he had taken chloral hydrate, and passes through all the stages of narcotism and recovery in the same way.

The action of metachloral is full of interest in a physiological point of view, and goes far, I think, to sustain Liebreich's original view of the action of chloral hydrate, viz. that the narcotism produced by it is due to the action of chloroform liberated within the body. On this view metachloral is first changed in the body, under the influence of alkali, into the soluble condition, after which it passes into the hydrate, and then into alkaline formate and chloroform. It is thus slower than the hydrate and slower than the anhydrous chloral in its action, but in the end the effects from it are the same. Metachloral admits of being employed medicinally; it may be combined with morphia, quinine, and other alkaloids, and will, I think, be found to possess many useful medicinal qualities.

Bromal Hydrate.

When bromine is made to act upon chlorine, a substance called bromal is the product. It is an oily substance like chloral, and when acted upon by alkalies is decomposed into formiate of the alkali employed, and into *bromoform*, the analogue in the bromine of chloroform in the chlorine series. The composition of bromal is C_2HBr_3O. When it is treated with water a crystalline substance, *bromal hydrate*, is produced. The composition of bromal hydrate is $C_2H\,Br_3\,O\,2H_2\,O$; it is the analogue in the bromine of the chloral hydrate in the chlorine series. Bromal hydrate has an odour somewhat like chloral hydrate; its crystals are very soluble in water, and it may be administered in solution by the mouth or by hypodermic injection.

Very soon after the discovery of the action of chloral hydrate I commenced a research on the physiological properties of the bromal hydrate. Two other observers also moved in the same path, and have preceded me in recording what they had observed. One of these is Dr. Steinann, of Berlin, the other Dr. John Dougall, of Glasgow. In their researches nearly the same class of inquiries were instituted as in my own, the same animals were subjected to observation, and practically the same results were obtained.

In order to produce marked effects from bromal hydrate, much smaller doses are required than of the corresponding chloral compound; five grains of the former are equivalent to ten of the latter. After an efficient dose the symptoms produced resemble in many respects the symptoms that follow chloral; *i. e.* there is great muscular prostration and a kind of narcotism, attended, however, with very slight insensibility, except in cases in which the dose has been dangerously large. In extreme cases only is there really deep

anæsthesia; in all cases there is sudden and extreme decrease of the animal temperature. In birds, rabbits, guineapigs, as well as in the human subject, these phenomena are observable. But there are other symptoms belonging to bromal hydrate which are peculiar to it, and which render its practical utility, according to our present knowledge of it at any rate, doubtful. It is intensely irritating; it causes great difficulty of respiration; it so suddenly and effectually reduces the animal temperature that the accumulation of fluid in the bronchial canals, from condensation, is a source of positive danger, and altogether its internal employment would be unwise. I agree with Drs. Steinann and Dougall as to the mode of its action, and, with them, attribute the phenomena to the effects of the bromoform that is liberated in the body after the dose has been administered; I agree also with Dougall that the cause of death, when the dose is fatal and slow, is due to asphyxia. I attribute the asphyxia primarily to the fall of temperature of the body, and secondarily to condensation of water in the bronchial passages.

One condition I have noticed which seems not to have fallen under the attention of the learned observers I have named, viz. that in birds a large dose of the bromal hydrate may destroy life almost instantaneously by an intense convulsion, amounting, in fact, to suddenly developed tetanus.

The chief interest at this moment attaching to bromal hydrate is the difference that is seen in its action, in comparison with the action of chloral hydrate. It illustrates how a difference of chemical elementary constitution and of weight modifies physiological action; how the heavier bromine in combination with carbon, hydrogen, oxygen, and water differs in action from chlorine in similar combination. The science of therapeutics will ultimately rest on these distinctions.

Nitrite of Amyl.

At the Meeting of the Association held at Newcastle-on-Tyne in 1863, I introduced this curious and potent substance to the notice of the Association, and explained, as best I could, its history and its physiological properties. Every year since then some new fact of interest has attached to the substance, and the immediate past year is not different in this respect from those that have preceded it. The first observer of the action of nitrite of amyl on the animal functions was Professor Guthrie, F.R.S., then of Edinburgh, and now of the School of Mines, London. Professor Guthrie observed, while working in the laboratory with nitrite of amyl, that the inhalation of its vapour produced flushing of the face, rapid action of the heart, a peculiar breathlessness, such as occurs after fast running, and disturbance of cerebral action. These facts, most ably described by the Professor, became known to Mr. Morison, a dentist in Edinburgh, who thought from them that the substance might be made of service for the treatment of persons who were suffering from faintness. He therefore brought some of the compound to the College of Dentists, a Society then existing in London, and the Council of that institution referred the whole subject to me, with a request that I would report to them. The task was readily undertaken, and the study connected with it has not been completed at this hour.

I take the liberty of mentioning these details for the sake of historical accuracy. From the circumstance that I have introduced nitrite of amyl greatly into medical practice, and have been year after year treating of its action, it has been all but universally believed that I made the *earliest* observations upon it; I would correct this error: I have worked industriously with nitrite of amyl, have studied carefully its mode of action, and have sug-

gested many new applications of it; but the credit of the earliest observations, as I stated at Newcastle, belongs strictly to Professor Guthrie.

It will be remembered by some that in one of my early papers on nitrite of amyl I pointed out that the effects observed were clearly due to an induced paralysis of the vascular system, of the terminal part of that system, and that the heart passed into vehement motion, not, as I at first had thought, because it was excited by the agent, but because the resistance to its action being removed, it ran down like a clock in which the resistance to the spring is broken by the removing of the pendulum or the pallets. I further explained that the seeming over-action produced by the nitrite was in truth no evidence of power or tension of muscle, but that in truth, under the influence of the nitrite, the muscular system is brought into extreme relaxation, so that the substance might be used as a remedy for the relief even of tetanic spasm. These views have been sustained by later observation. It remained, however, still to discover how far the relaxation of vessels from nitrite of amyl extended to the functions of special organs of the body; and during the present year I have followed up this line of research in respect to the changes producible by it in the pulmonary organs, the lungs. The study has been most fruitful, and will, I think, as it is followed up, open quite a new field of accurate and sound observation as to the mode in which many diseases of the lungs take their origin.

As there may be many here who are not conversant with the nature and properties of nitrite of amyl, I may say briefly, in respect to it, that it is an amber-coloured fluid, having the odour of ripe pears, and, although requiring a high temperature for ebullition, volatilizing very readily on exposure to the air.

When taken into the body nitrite of amyl produces intense flushing of the face, throbbing and sensation of fulness in the head, rapid action of the heart, and in time a sense of breathless exhaustion. In my previous Reports I have entered at length into details of its action, of which the following is a summary.

The nitrite, though insoluble in water, will enter the body and produce its specific action by any channel of the body, by the cellular tissue, stomach, blood. It produces general muscular paralysis, affecting directly or indirectly all the motor centres.

It exerts no primary action on the sensory centres, and therefore does not produce anæsthesia.

Its paralyzing action seems first to be directed to the organic nervous centres, by which the vascular tension is reduced. It acts, in fact, after the manner of an emotional shock, leading quickly to paralysis of the minute vessels.

It prevents oxidation by its presence, and possesses distinct antiseptic powers. It produces a peculiar tarry condition of the blood, but does not materially impede coagulation.

It neutralizes the tetanic action of strychnia, and removes tetanic spasm.

On reviewing these inferences of former years, as thus detailed, I see no occasion to change one of them; indeed I believe they have, on the whole, all been confirmed by other observers. The admirable experiments of Dr. Brunton on the action of the nitrite on vascular tension call for special recognition. There is, however, one observation in my Report of 1864 I would like to correct. Speaking at that time of the action of the nitrite on the muscles, I remarked that it first excites the muscular system, and then paralyzes it. I am in doubt now whether the muscular excitement of which I

spoke in 1864 is a true excitement due to the influence excited by the agent on the motor centres. I think, from my own sensations, it is rather due to an indirect or mental impression, that it indicates a vehement desire to escape from the influence of the agent, like the excitement of fear or frenzy.

Let me from these points turn to the observations of the past year. I observed long ago, in making dissections of the bodies of animals that had died from amyl nitrite, that the condition of the lungs varied much, that sometimes the lungs were of milky whiteness, sometimes of leaden hue, and again of deep dark red hue. It occurred to me at last that these differences were not accidental, but that they depended upon the mode in which the agent destroyed the life of the animal. Thereupon I made direct inquiry into this subject, and was led to discover that I could, practically, modify the circulation of the blood, passing over the lung from the right to the left heart, as I pleased; in other words, I learned that the vessels of the lungs are influenced by the nitrite in the same manner as the vessels of the skin.

The observation thus stated led me naturally a step further. I inquired as to results of different temporary lesions that might be inflicted on the pulmonary organs by the nitrite, and what extremity of lesion could be recovered from under conditions favourable to recovery. I commenced this research in February last, and have carried it on without intermission from that time: the results of the labour have been most instructive.

There are four distinct conditions of lung producible by nitrite of amyl; there may be more, but I know of these:—

1. If the animal be destroyed by an overwhelming dose of the agent, so that it dies instantly, as it might die from syncope, the lungs are left absolutely bloodless and of pure whiteness. The right side of the heart is in this case paralyzed; but exposed to the air immediately after death it often recovers its power of contraction. In this instance the death is really by syncope; the nervous paralysis is extended immediately to the heart, probably from paralysis of the sympathetic supply, and the right ventricle failing to pour out its blood to the lung, the death is so instantaneous that there is no time left for the production of any organic change.

2. If the death be comparatively slow, if it be preceded by a short interval of muscular prostration, and if it occur from paralysis of the muscles of respiration, then the lungs are left charged with dark tarry blood, but they contain air and are free of congestion. Here the lungs and heart have failed together, and the balance of the pulmonary circulation has been fairly maintained.

3. If the effect of the nitrite be more definitely prolonged, there is produced intense general congestion of the pulmonary vascular system, a congestion so intense that the lungs, full of blood, dark and heavy, will not float in water. The cause of death in this instance is progressive neural paralysis of the pulmonary vessels; it is the equivalent of congestion of the lungs from long expose to extreme cold.

4. The above may all be considered as acute changes in the pulmonary structures, and the two first-named changes are immediately fatal. The last need not be; as it occurs from prolonged and sustained action of the nitrite, in quantities insufficient to kill directly, the effects of sustained congestion may be traced out from day to day for many weeks.

To be accurate in the observations made on this subject, I constructed a glass house or chamber of a capacity of three cubic feet, and so ventilated it that the air could be kept charged with the vapour of the nitrite. In this chamber rabbits and guineapigs were housed. They were carefully fed,

supplied with abundance of air, and well protected from cold. The introduction of the vapour was so moderated that the same quantity was made to undergo diffusion each day.

The first fact that became well established was, that cold and a low barometric pressure greatly assisted the action of the vapour, and frequently led to sudden death from congestion of lung and accumulation of fluid in the bronchial tubes.

A second fact, of singular interest, was the degree to which recovery from extreme congestion of lung would take place, on simply withdrawing the animal from the influence of the agent. When the lungs were so obstructed that what is called rale from accumulation of mucous fluid in the bronchial surface was most marked, there was invariably a rapid recovery on removal to fresh and warm air.

A third fact relating to the lesions induced, beyond mere congestive lesions, is also of deep interest. The lesions were primarily all of one kind; they were hæmorrhagic, and consisted of red spots and patches, in which blood was effused and coagulated in the connective tissue. The position of the hæmorrhage was singular. In three cases it was only in the extreme point of the apices of the lungs; in four other cases lower portions of lung were involved, but in these the apices were the seats also of hæmorrhagic disease. It would appear, in fact, as if these points of lung were least resistant to the force of the circulation.

In the animals observed these distinct hæmorrhagic changes were usually fatal, so that the further result of the local neural paralysis could not be carried out as could be wished. In two cases, nevertheless, we had other results worth recording.

In one instance there was clearly an œdema of the lung structure: in another the pleural membrane was raised in four or five granulated points, round each of which there was effused blood. Dr. Sedgwick, who took the lungs of this animal for careful microscopic inspection, reported to me that there were plastic exudations in various parts of both lungs, and that the granulations of which I have spoken consisted of effused plasma beneath the pleura.

I am well content to leave these observations as I have written them above, with but two observations more. It has been suggested by an accomplished and acute English physician, Dr. Eade, of Norwich, that pulmonary consumption may be primarily due to pulmonary vascular paralysis. My experiments do not enable me at this stage to endorse Dr. Eade's hypothesis as to the primary origin of consumption, but certainly they indicate to what extent nervous deficiency will go in favouring the hæmorrhages, congestions, and exudations which attend tubercular disease.

The concluding observation this year with nitrite of amyl relates to the fact that the nitrite atmosphere, when it is not too much charged with the vapour, exerts a certain curative effect. Three rabbits were brought to me with a skin disease resembling lepra in man. They were emaciated and feeble, the fur on the back along the whole length of the spine had been cast off, and the skin was covered over this part with white ashy scales.

Placing these animals in an atmosphere of nitrite of amyl, I noticed that, as the agent took effect, the scaly white skin on the back became red and flushed. In a day or two the scales disappeared, the fur began to extend, and the general health to improve. In a month all the animals had entirely recovered.

There are many local conditions of disease in man and other animals in

which the essence of cure lies in reestablishing a good capillary circulation. It may be, therefore, that by administering the nitrite of amyl, or the other organic nitrites, *secundum artem*, we may make them further agents in the cure of disease, and thereby add another progress to physiological as distinguished from empirical medicine.

Nitrate of Ethyl.

In one of my previous Reports I touched incidentally on certain of the nitrates of the organic series of compounds. These substances differ from the nitrites simply in that they contain an additional equivalent of oxygen. It is a very interesting study to follow the difference of physiological action upon so simple a change of chemical constitution; and this year I studied once more this difference from two of the representatives of the nitrate series, viz. from nitrate of ethyl and nitrate of amyl.

Nitrate of ethyl, to which I first refer, is a fluid, almost colourless, and yielding an agreeable odorous vapour. It has a specific gravity of 1·112, a boiling-point of 85° C. (185° F.), and a vapour-density of 45. Its composition is $C_2H_5NO_3$. It is made by dropping 10 grms. of absolute alcohol into 20 grms. of colourless concentrate nitric acid in a platinum vessel surrounded by a freezing-mixture. Mr. Ernest Chapman was kind enough to make me a fine specimen of this nitrate, with which my experiments have been conducted.

Nitrate of ethyl was used in experiment, physiologically, in 1848, by the late distinguished Professor of Midwifery in the University of Edinburgh, Sir James Simpson. Sir James considered that it possessed some anæsthetic properties. It has for many years, I may say centuries, also been used in medicine, in combination with alcohol, under the name of nitric ether, and so employed has been considered valuable for its diuretic properties.

I find, on using it in the undiluted form, that it may be introduced into the system either by inhalation, by hypodermic injection, or by the stomach, and that the effects which follow its administration in large doses are closely analogous to those induced by nitrite of amyl, *i. e.* it produces rapid action of the heart, some pulsation of the vessels of the head, flushing of the face, and muscular prostration. In the strict sense of the word, it is not an anæsthetic; when administered in an extreme dose, there is no evidence of insensibility until death is imminent. In all cases the motor force is overcome completely long before the sensory organs are influenced. The paralysis of the vessels is slower than from nitrite of amyl; the danger of using the agent is consequently much less; and as the effects are more prolonged, the substance becomes very manageable in medical practice.

When the administration of the nitrate is carried up to death, the condition induced in all the vascular organs is an intense congestion. In this congestion the lungs and the kidneys specially share; and I think there is no doubt that the well known diuretic action of the substance is due altogether to the paralysis of the renal vessels it produces. It alters much less than the nitrites the colour of the blood, interferes in no way with the process of coagulation, and is eliminated rapidly from the body both by the lungs and the kidneys. Administered to the production of complete prostration, it reduces the animal temperature in a definite degree. In pigeons the temperature goes down five and even six degrees, in rabbits three degrees, and in guineapigs from two to three degrees. Like the nitrites, nitrate of ethyl reduces the tetanic spasm of strychnia; and I would suggest that in tetanus, and other acute diseases of spasmodic character, it might be used

with great advantage; but it must be given for this purpose in very different proportions to those in which it is now commonly prescribed. The best plan would be to administer it by inhalation until a decided influence over the motor action is manifested. In pharmacy it would be convenient to keep the nitrite in the pure and simple state, leaving the dilution of it, in alcohol, to the judgment of the physician.

Nitrate of Amyl.

Nitrate of amyl, $C_5 H_{11} NO_3$, is a pale amber-coloured fluid, of not very agreeable odour. It has a specific gravity of 0·992, a boiling-point of 138° C. (280° F.), and a vapour-density of 66°. It is made by acting with strong nitric acid, 30 grms., on urea nitrate, 10 grms., adding afterwards 40 grms. of pure amylic alcohol. I am again indebted to Mr. Ernest Chapman for a specimen of nitrate of amyl, freed as far as possible from nitrate of butyl, from all trace of which it can with difficulty be separated.

In the nitrate of amyl we have a substance differing chemically from nitrite of amyl in having an additional equivalent of oxygen, and differing physically in that it is heavier and of higher boiling-point. It enters the body readily by all channels, and in its general effects it agrees with the nitrite, except that a longer time is required for the development of symptoms from it, and a longer time is demanded for the process of recovery from its influence. The quantity necessary to produce decisive results is the same as with the nitrite; but the nitrate is not so pleasant a substance to administer, and when administered by inhalation is not so conveniently applied. Whether the nitrate of amyl has any real advantages over the nitrite is a question on which I would prefer not to speak at length, until larger opportunities than I have yet had of proving it have been afforded me.

Sulpho-urea.

In my last Report I treated on the physiological properties of certain of the organic sulphur compounds, viz. sulphur alcohol, mercaptan, and sulphide of ethyl. Recently a very curious and interesting sulphur compound has come before me for experiment; I mean a crystalline substance known by the name of sulpho-urea. Sulpho-urea was first made, I believe, by Prof. Reynolds, and it has since been produced in London, in Dr. Thudichum's laboratory, by Mr. Charles Stewart, to whom I am indebted for the specimens with which I have conducted my researches. Unfortunately the manufacture is difficult, owing to the necessity for many recrystallizations, so that I have only been able to work with six drachms; but the results, as far as they go, deserve notice. Mr. Stewart has kindly given me the following note in regard to the preparation of sulpho-urea:—

"About a kilogram of pure ammonium sulphocyanate is dried at 100° C., powdered, and dried again. Slight loss by sublimation occurs. When perfectly dry, it is heated *gradually* by a paraffin bath to 170° C., and maintained at that temperature for two hours. The mass is then allowed to cool to 110° C., treated with one and a half times its bulk of boiling water, decanted from a small quantity of black matter (it is impossible to filter it, as it destroys paper filters), and set aside to crystallize. The crystals are long, fibrous, satiny needles; they are drained, pressed strongly in Hessian cloth, and purified by recrystallization from water. The product is then dissolved in boiling alcohol, filtered from a little *ammonium sulphate* which remains undissolved, and set aside to crystallize. Two more crystallizations from alcohol

render it practically free from sulphocyanate. The crystals from alcohol are hard, opaque, white prisms: from water they are long, fibrous, silky needles. Both forms are anhydrous." I present specimens of both varieties.

"From the mother liquors more of the urea may be recovered by the same process. The last mother liquors, containing mainly sulphur urea, but also much sulphocyanide, may be evaporated down, and heated again to 170°, as above, with fresh sulphocyanide of ammonium, to furnish more urea."

Sulpho-urea is much less soluble in water than ordinary urea, requiring twice its own weight, at 60° F., for solution. It has a saline bitter taste, compared by some to the taste of magnesian sulphate. It differs simply from ordinary urea in that in it sulphur replaces oxygen.

$$\text{Urea.}\quad \left.\begin{matrix} CN \\ NH_4 \end{matrix}\right\} O, \qquad\qquad \text{Sulpho-urea.}\quad \left.\begin{matrix} CN \\ NH_4 \end{matrix}\right\} S.$$

In order to determine the difference of action of the two ureas, a series of comparative experiments were carried out. The results may be thus epitomized:—

On frogs and rabbits sulpho-urea differs materially from common urea in its action, *i. e.* when used in the same quantities. The first produces definite convulsive action, with coma and convulsion; the second produces, in frogs, coma without convulsion, and in rabbits nothing more than a slight and gentle soporific condition, which lasts for a very short time, and can be broken at any moment by the simple act of moving or calling out to the animal.

In frogs sulpho-urea induces the saline cataract, common urea does not.

To produce any decided physiological effect with sulpho-urea, the proportion used must not be less than thirty grains to the pound weight of the animal. In three experiments in which it was administered to young rabbits, to the extent of producing slight soporific effects, it reduced the animal temperature two degrees Fahrenheit within the interval of an hour.

The impression I have gathered in respect of sulpho-urea is, that it is a saline narcotic, and as such it may prove of use in medicine; but the great point of physiological interest in connexion with it lies in the difference indicated, by its means, between the action of oxygen and sulphur in combination with the same elements, C, N, H, in the same form. The difference may be due to the difference of weight, or it may be due to difference of solubility; the elements, oxygen and sulphur, producing the distinction by virtue of their physical qualities of weight or solubility; or it may be due to the special qualities of the elements. I offer these thoughts as again bearing upon the general question of chemical composition in relation to the physiological action of chemical substances.

Chlor-Ethylidene—Monochloruretted Chloride of Ethyle.

In the year 1852 Dr. John Snow introduced as an anæsthetic the monochloruretted chloride of ethyle. He administered the vapour of this substance many times to the inferior animals and to the human subject, and he came to the conclusion that the vapour was equivalent in value to chloroform, and had an advantage over chloroform, viz. that it rarely if ever produced vomiting; it did not usually excite the stomach, he observed, even if it were administered after food. In 1870 the distinguished Liebreich, who evidently was not aware of Snow's research, reintroduced this anæsthetic under the name of chlor-ethylidene. Chlor-ethylidene yields a sweet etherial vapour,

less pungent than vapour of chloroform, but still pungent; the vapour burns in air. The specific gravity of the fluid is 1·174, the vapour-density 49, the boiling-point 64° C. (149° F.). The composition is $C_2H_4Cl_2$. It differs from Dutch liquid, which in other respects it resembles, in not being decomposed by an alcoholic solution of potassa (Snow).

I had already seen chlor-ethylidene in use in 1852, and had added Snow's memoir upon it (during the writing of which, by the way, he was taken with his fatal seizure) in my edition of his works on anæsthesia, published in 1858; but since the subject has come up again I have travelled once more over the same ground. I obtained a specimen of chlor-ethylidene, administered it several times for the production of anæsthesia, and am bound to say of it that it is a very good anæsthetic. It resembles bichloride of methylene very much in its action, produces vomiting as rarely, but is less rapid than the bichloride, being of higher boiling-point and yielding a heavier vapour.

On inferior animals I find that when carried to extremity it arrests the respiration before it arrests the action of the heart; and I also find that recovery from its extremest effects is comparatively easy. In one of my lectures during the past winter session I restored life in a rabbit, by careful artificial respiration, seven minutes and a half after all signs of natural respiration had been abolished by the vapour of chlor-ethylidene.

I would give to chlor-ethylidene a prominent place amongst anæsthetics. It would take the place of either chloroform or bichloride of methylene efficiently; it is safer than chloroform, and excites vomiting less frequently; it is less rapid in action than methylene bichloride, not more effective, and possesses, I think, about the same value in matter of safety.

Hydramyle.

At the Meeting of the Association at Exeter I placed before this Section a fluid called hydride of amyl. The fluid had a specific gravity of ·625, and it boiled at 30° C. (86° F.). Its composition was stated to be $C_5H_{11}H$. I described then that this vapour was a quickly acting anæsthetic.

During the present year I have experimented largely again with this hydride, with the view of rendering it applicable for the production of rapid anæsthetic sleep, for short operations, such as extraction of teeth. In this research I found one or two difficulties in the way. The fluid was too light to be manageable on every occasion; that is to say, it escaped from the inhaler, as a gas, by the mere warmth of the breath, and the vapour had also an odour which to the majority of persons was objectionable.

I set to work to obviate these difficulties, first by slightly weighting the fluid, and secondly by making an inhaler that should more effectually restrain the liquid as it was undergoing evaporation. In both attempts I have succeeded well.

In making good bichloride of methylene we put finely pulverized zinc into a retort and pour upon it absolute alcohol and chloroform, using afterwards a heat not exceeding 120° F., in order to distil over the product. I modified this process by diluting the mixture of chloroform and alcohol with eight times the volume of hydride of amyl. This mixture is poured upon the zinc, with the result of an instant vehement action without any application of heat; after a free evolution of gas, which lasts some minutes, there distils by this method a fluid which contains pure hydride of amyl and pure bichloride of methylene. If the distillation be carried on at 98° F., the fluid that comes over has the specific gravity of ordinary ether (·720), a most agreeable odour, and rapid anæsthetic action. I have now administered this

fluid, in vapour, forty-six times for short operations on the human subject, and in the average of cases have produced the required insensibility within fifty seconds. In one instance insensibility was produced, a firm tooth was extracted, and perfect recovery occurred in forty seconds. As yet there has neither been vomiting nor other untoward symptom during the administration.

There is, however, a peculiarity in the action of this vapour to which I ought carefully to refer, viz. that insensibility from it intensifies after the inhalation of it is withdrawn. Thus in administering, whenever there is the least indication of its effects, such as winking of the eyelids or drop of the hand, the sign is given to stop the administration. The operator may now wait a few seconds and then proceed. The inhaler I have constructed for the administration of this new anæsthetic is before the Meeting. It is a simple hollow cone made of leather, and is furnished with two light silken valves for entrance of air and exit of vapour and breath. It is lined with domette set on a light frame or ring of metal. When the inhaler is not in use it forms a case for holding safely, in a bottle, four fluid-ounces of the anæsthetic liquid. This quantity is sufficient for twenty operations, of from one and a half to three minutes' duration, two drachms being the amount necessary for an operation not exceeding three minutes' duration.

The vapour described above will become, I believe, should experience confirm its safety, of general application as an anæsthetic for short operations; for long operations it will probably not replace the heavier anæsthetics. I am indebted to Mr. Ernest Chapman for the suggestion of the abbreviated name hydramyle.

PHYSIOLOGICAL NOTES.

In the course of the researches detailed in the preceding pages I have again, as in previous researches, been led to notice certain simple facts which lie in the path of inquiry, and which, though not necessarily belonging to it, are too prominent to be passed by without notice. I shall therefore offer a few notes bearing on three topics; and this the more readily, because it is rarely the case that so many eminent physiologists as are now present, each one interested in the subjects to be named, meet together to take part in discussion.

Effect of some Narcotic Vapours on the minute circulation of the Blood.

I have taken occasion several times to observe the effect of narcotic vapours on the minute circulation of the blood. I prefer to use the term "minute circulation" because it embraces the minute arterial and venous, as well as the capillary circulation.

In these researches the web of the foot of the frog was selected for observation, and I think on the whole with advantage. The following particulars were carried out in every case:—

(*a*) A large healthy frog was chosen, and one in which the web was very clear. (*b*) The same microscopic power, and that low—the inch or half-inch object-glass and A eye-piece (Ross)—was always employed. (*c*) The temperature of the air was kept the same during periods of observation, and the work was conducted during the same hours each day, viz. between the hours of 2 and 5 P.M. (*d*) The observations were never hurried; they occupied an average of three hours each, and every change of scene in the vessels through the various stages of narcotism and of recovery were carefully and systema-

tically noted. (*e*) The animals were placed for narcotism in the small glass chamber now before the Members. The chamber as it is was finally constructed, after many essays, by my friend Dr. Sedgwick, and it answered admirably. The animal was placed, without any restraint, in the chamber; one foot was then gently drawn out on to the stage attached to the chamber, and the web was extended over the small glass plate. The animal being thus prepared, the web was brought under the microscope and the circulation examined. (*f*) The part of the circulation to be observed was so selected as to include a good view of an artery, a vein, and the smaller intermediate capillary vessels. (*g*) When the natural condition of the circulation was well observed the chamber was closed by the sliding cover, and through it the narcotic vapour, the effect of which upon the circulation was to be investigated, was gently passed. The vapour was driven over with hand-bellows from a small Junker's apparatus, manufactured by Messrs. Krohne and Sesemann*. By counting the strokes of the bellows it was possible to maintain the same current of vapour at all times. (*h*) And lastly, the web was sustained in the same condition of moisture, so as to prevent errors of observation due to evaporation from the tissues.

Such were the precautions taken; and I am inclined to think they were sufficient, although it will be a great satisfaction to me and an aid in my future labours to hear of any amendments or additions that may be suggested. The narcotic vapours used in the research were hydramyle, chloroform, bichloride of methylene, and absolute ether. In some particulars these acted precisely in a similar way, in other particulars they acted in a way more or less peculiar to themselves.

The first fact I would notice as common to the action of all the vapours used is, that no obvious change in the physical characters of the blood-corpuscles, red or white, was ever observable; neither was there any noticeable difference in the relationships of the red and white corpuscles to each other. The red corpuscles held their ways so long as there was motion in the centre of the blood-streams, while the white ones rolled along by the sides of vessels in the same manner as they did before the narcotism.

Another fact common to the action of all the vapours used was, that the first sign of arrested movement of the circulation commenced in every case on the venous side of the circulation, and consisted of a sort of pulsation or to-and-fro movement of the current through the vein; soon upon this the venous current became obviously slower and the vein dilated, while the arterial current remained, often for a long time, unchanged.

In every case the minute circulation remained long in force after the respiration had entirely ceased, and after all evidence of the continuance of life had entirely ceased. On the average the animals ceased to breathe for one hour and thirty minutes after the deep narcotism had set in; yet all the while the minute circulation was still playing with more or less of efficiency, and so long as it continued the chances of recovery were nearly certain. The cessation of the minute circulation was, on the other hand, the sign and proof of irrevocable death.

There was still another effect common to all the narcotics used. The circulation through the capillaries often stopped altogether, and for considerable intervals of time, when the reduction of the circulatory power was greatest. Under this condition the circulation, such as it was, was maintained by the arteries, in which the blood moved to and fro with occasional slow steady

* Dr. Richardson here fitted up the apparatus, including small chamber, hand-bellows, and Junker's bottle, and showed the method by which it was worked.

onward movements. In the veins, too, there were now and then short movements, first as of impulse towards the heart, and then of retreat backwards; these movements in the veins were succeeded invariably by an increased and more perfect action of the arteries. During this state the capillaries may be said to have become almost indistinct, that is to say, no movement of corpuscles through them, into the veins, indicated their course; as channels they were left empty and transparent, and the return of the corpuscular current through them was at all times proof of the speedy return of the activity of life.

The changes named above were common to the action of all the narcotics named; but there were some striking changes peculiar to the substances themselves to which I must refer. The peculiarities were traceable, as it seems to me, to the weight, the solubility, and the chemical composition of the substance that was employed to produce the narcotic state.

When the substance was very light, of low boiling-point, and insoluble, the effect of arrest of the circulation was most rapidly developed, and at the same time was most rapidly removed. Thus hydramyle, the lightest, the first to boil on elevation of temperature, and the most insoluble, produced the quickest arrest of the venous current; but from its influence the animal was equally quick to recover, the general signs of recovery being secondary to the local return of the circulation.

When the substance was light and of low boiling-point, but comparatively soluble in blood, the time required to produce the slowing of the venous circulation was prolonged after the insensibility of the animal was complete; after even respiration had stopped, the extreme changes in the circulation were slowly developed; and although the insensibility might be deep and continuous, like to death itself, the actual temporary arrest of the arterial current was imperfectly pronounced. Absolute ether, which has a very low specific weight (720) and a very low boiling-point (94° F.), but which is soluble in blood to the extent of not less than eleven parts in the hundred, produced perfectly all the effects immediately named above. When the substance inhaled was comparatively heavier, of a higher boiling-point, insoluble, and contained as one of its elements an irritant, there was introduced a new phase, that is to say, the arterial vessels, as the animal came under the influence of the narcotic, were reduced in calibre. The changes of the circulation in this case were first marked in the retardation of the blood through the veins, then the vein increased in diameter, and there were signs of regurgitation of its blood; these indications were followed by what may be called irregular movements in the capillaries, and by reduction of calibre of the arteries. It was observed, nevertheless, that the narrowing of the arterial vessels, though well marked, was never so extreme as to prevent motion of blood in them; that is to say, the degree of arterial contraction was limited. I consider this to be due to the circumstance that the animal had always ceased to breathe, and the further absorption of the narcotic vapour had consequently also ceased, by the time that the action of the vapour upon the arterial vessels was developed.

During the period when the size of the arterial vessel was reduced, the motion of the blood in the capillary vessels fed by the arterial supply was modified; the blood flowing through the capillary channels moved less steadily, and was forced, if I may so express the fact, in pushes, as if there were intervals of relaxation of the arterial vessels during which the resistance to the impelling power of the heart slightly and slowly yielded. After a time the circulation of the blood through the artery became slower,

the capillaries were left empty, the venous current ceased, and the condition of temporary suspension of all circulation, except slowly, in the arterial supervened. The effects here named were well marked from the action of the chlorides; they were seen under the influence of bichloride of methylene, they were still more definite under chloroform.

To sum up, if my observations be correct, the action on the systemic circulation of the narcotic vapours named was seen to be primarily on the venous current or, I should more correctly say, was primarily manifested in the retardation of the venous current, secondly in the capillary, and finally in the arterial current. During recovery, moreover, the return of a steady onward current was manifested in the veins before it was restored in the capillary channels. This order of events coincides purely with the order of phenomena of death under the influence of narcotic vapours, as observed both in man and the lower animals. It is, I think, the invariable fact that the right side of the heart in such fatal cases is the first to cease its action, and in animals, when the heart is exposed to the air soon after the death, the right side is the first to recommence action. From these facts the inference, I think, is clear that the arrest of the circulation begins, during the narcotism, in the retardation of the venous current, secondly in the capillary, and lastly in the arterial current.

The course of recovery, when recovery takes place, appears to be preceded by some act of relief to the venous column of blood. The motion that remains in the arteries is not the first to increase, the circulation through the capillary is not first manifested; that which happens, as a distinct sign of recovery, is a movement onward by the veins; as this movement improves the movement through the arteries improves, the capillary vessels refill, and the circuit of the minute circulation is steadily and perfectly restored.

From these observations on the minute systemic circulation when the body is under the influence of a narcotic vapour of the irritant class, I infer that the changes of circulation observed do not proceed immediately from an action exerted by the narcotic vapour upon the extreme systemic vessels, but form an obstruction commencing on the venous side, and in the lesser or pulmonary circulation. When a warm-blooded animal is suddenly killed by a large dose of the vapour of chloroform, the lungs are invariably found blanched, the right side of the heart engorged with blood, and the left side empty of blood. We see in these conditions that of necessity, in the extreme parts of the systemic circulation of the animal, there has been retardation of the blood through the veins; and we may infer on the fairest, nay completest, evidence that the return of motion, which is seen commencing in the veins in the systemic circuit, is due to a returning current in the breathing-organs; in other words, the renewal of the active life of the animal recommences in passive breathing. The same order of phenomena happens, precisely, during the recovery of a warm-blooded animal, after apparent death from chloroform, under the influence of artificial respiration; for so soon as the animal recommences to breathe, however faintly, its return to life is secured.

The position then assumed, that the primary arrest of the column of blood during fatal narcotism is in the lesser circulation, we have to ask whether the arrest commences in the heart or in the lungs. The commonly accepted view has been that it commences in failure of the right side of the heart; but I incline to think that this view is incorrect, and that the positive source of failure is in the peripheral circulation of the lung. The vapour inhaled impresses, I think, *immediately* the minute circulation, and acts not by absorption into the blood, but by simple and instant contact with the minute

pulmonary vessels, so that there is immediate resistance to the passage of blood through them. Three well-observed facts support this opinion:—1st, the fact already dwelt upon, that in cases of rapid death the lungs are emptied of blood; 2nd, that the arrest of the systemic circulation commences on the venous side of the circulation, and is attended with filling of the veins; 3rd, that immediately after the death of the animal, if the chest be opened and the heart exposed, the right side of the heart, relieved of pressure, will immediately recommence to contract vigorously, showing that it is not itself paralyzed, but is restrained from action by mechanical resistance to its column of blood.

If the theory of the action of narcotic vapours thus propounded be correct, we ought to draw from it this practical lesson, that in introducing new narcotic vapours into practice, the utmost care should be taken to select those only that are negative in respect to their action upon the vessels of the minute circulation. A gas or vapour that asphyxiates but does not irritate may be safer than a gas or vapour that does not asphyxiate and does irritate; for the former, when it kills, kills by a secondary process that is preceded by a series of symptoms foretelling the danger; while the latter, when it kills, kills often by instantly shutting off the column of blood that is making its way to the air, and by so oppressing the heart that every attempt at action, under the condition produced, increases the injury.

On Convulsive Movements during Narcotism.

I have endeavoured to show in the last section that under narcotism from certain narcotic vapours, the vapours of the chlorine series specially, there are two orders of cessation of the circulation,—the one primary, beginning in the lesser or pulmonary, the other secondary, beginning in the larger or systemic circulation. Coincidently with these changes I have, I think, observed, when there has been time for the development of the phenomena, two distinct series of convulsive movements or paroxysms of convulsion. I have noticed the same fact in drowning, and also in fatal sudden hæmorrhage, as in the process of killing animals, such as sheep. The phenomena may at any time be observed at the abattoir; they are in fact perhaps best seen in cases of rapid fatal hæmorrhage; and I am led to the conclusion that they have one common interpretation as to cause, the hæmorrhagic convulsions being the purest type of all. The convulsive actions, primary and secondary, are due, as it seems to me, to disturbance of the balance of supply of blood to the nervous and muscular centres. As a mechanism, the mass of nervous matter is the centre of reserved force, while the mass of muscle is the moving centre, the two centres being connected by an intervening nervous cord, and each supplied with the same blood. The two centres are held in counterpoise, as it were, by the blood. If there be, then, any disturbance of support in either centre, it will be indicated in change of function in the moving centre, in change of motion.

When we draw blood from the systemic circuit, or when through the lesser circulation we arrest the free current of blood through the systemic circuit, we destroy the balance previously existing between the muscular and nervous centres. If we could so exhaust the body that both centres should be exhausted together evenly, it is possible that there would be no change of motion in the moving centre; and, indeed, in some cases of disease we see the gradual and equal exhaustion without manifestation of the convulsive phenomena. But in cases of extreme and sudden break of balance, it follows necessarily that the balance shall be broken unevenly. It is in the muscular system

that the failure of blood is first felt. The nervous centres, protected from the effects of sudden pressure by their envelopment of bony structure, feel the shock of the exhaustion secondarily. Thus the muscle suffering a reduced resistance of blood to the nervous stimulus, contracts as if it had received an excess of stimulus, and the phenomenon of primary convulsion is developed; in hæmorrhage this convulsion immediately precedes deliquium or syncope. In brief time, the nervous centres themselves becoming exhausted, the convulsions cease, and none but the muscular movements of the organic life, respiration and circulation, remain. These while they last feed still in a passive state the nervous centres and muscular centres; and if the cause of exhaustion at this stage be stopped and the body be resupplied with means of life, recovery takes place without the necessary return of convulsive action; but if the exhaustion proceed, then follows the secondary phase, the failure of the organic system, and with that a repetition of the phenomenon of primary failure, viz. a second general convulsion, terminating in death.

The convulsion of hæmorrhage is, I repeat, the typical form of the conditions I have portrayed; but in death from chloroform and similar narcotics, the phenomena are sometimes equally striking. The convulsion and rigidity which mark the second degree of narcotism indicate the first break of balance between the nervous and the muscular centres; the period of the third and fourth degrees of narcotism, during which there is complete paralysis of voluntary and of conscious power, marks the interval when all life is suspended on the organic or vegetative nervous system; the final convulsion that precedes death marks and proclaims the moment when the organic force itself breaks down, leaving the whole organism motionless and, as we say, dead.

On Condensation of Water on the Bronchial Surface during Narcotism.

It has occurred to me often to observe that the physiological action of narcotic vapours during inhalation is greatly modified by the condition of the atmospheric air in respect to its dryness and its moisture. When the atmosphere is extremely dry, the action of a narcotic vapour is greatly increased, and recovery from its effects is remarkably easy; on the contrary, when the air is saturated with water vapour the action is impeded; and if the air be at the same time cold and moist, the process of narcotism is often greatly impeded, while recovery after it has been established is prolonged in proportion. But the fact I wish particularly to bring forward is, that when the body of an animal becomes profoundly narcotized, and the insensibility is long maintained, during conditions in which the air is cold and moist, there occurs not unfrequently an actual condensation of water in the minute bronchial passages, which condensation leads to as low asphyxia, and, if it be continued, to actual death. This accident is best seen in cases of narcotic poisoning from hydrate of chloral; it may also be observed after poisoning from opium and other narcotics, as well as after long exposure to extreme cold.

There are two causes at work to produce the condensation: the one is the obstacle to evaporation of watery matter from the surface of the animal membrane into the air; the other the deficiency of force, in an animal whose general temperature is reduced, to raise the vapour of water from the blood, and to expel it from the pulmonary organs in the state of vapour.

Whenever in any case condensation of water, from the causes named, is set up, the danger continues in an increasing ratio; for the condensation tends to shut off the air from contact with the blood, the temperature of the

body (dependent always on the perfection of the respiratory process) decreases, and at last the respiratory change is prohibited altogether.

It is important in the extremest degree to remember the fact thus named in the treatment of cases of poisoning during which the animal heat is reduced. It will often turn the scale, in such instances, in favour of return to life, simply to place the body in a warm and dry air.

The fact is also of great interest, in a practical and physiological point of view, in relation to the phenomena of some exhaustive diseases. The cold sweats that are seen on the surface of the body in syncope, in the later stages of phthisis pulmonalis, and on the approach of death in many diseases, as also the chest-rattles, are due to the cause I have named above—condensation. They are evidences that the body has not sufficient power or force to produce a rapid natural evaporation of water from the exhaling surfaces.

Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for the purpose of showing their structure by means of Photography. The Committee consists of James Thomson, *F.G.S., and* Professor Harkness, *F.R.S.*

In our Report of last year we gave in detail the probable additions to our present list of fossil corals from the Mountain Limestone.

During the past year we have had several hundred specimens cut. Although many of these have been more or less spoiled, and their internal structure crushed and broken to such an extent that their specific characters cannot with any degree of certainty be made out, yet many of them reveal important structural characters which will enable us to add both genera and species to those before indicated. Many of the specimens cut have well-preserved calices, which will enable us to figure and describe both their internal structure and external aspect, with a degree of certainty hitherto unknown.

Although much progress has been made, we are convinced that many other facts will be revealed by further investigation; and we hope the Committee will be reappointed in order that we may continue this important inquiry.

We have not added any additional photographic plates to those exhibited last year at Liverpool. We were desirous of getting as large a number of specimens cut as the sum at our disposal would permit, in order that we might select the most characteristic generic forms for further plates.

At Liverpool we indicated that we were in the hopes of reproducing the most delicate structures by another process, which would be more serviceable for the purpose of publication. In this we are glad to state that we have been successful. By a simple process we are enabled to transfer the details of both genera and species to copper plates, from which any number of copies can be reproduced, of which we will avail ourselves when we are ready to publish *in extenso*. (Two plates so prepared were exhibited.)

We have placed in the British Museum and the Hunterian Museum of Glasgow duplicates of a number of the cut specimens which have already been described; other duplicates will be sent when they have been described and named.

Second Report of the Committee appointed to consider and report on the various Plans proposed for Legislating on the subject of Steam-Boiler Explosions, with a view to their Prevention,—the Committee consisting of Sir William Fairbairn, *Bart., C.E., LL.D., F.R.S.,* John Penn, *C.E., F.R.S.,* Frederick J. Bramwell, *C.E.,* Hugh Mason, Samuel Rigby, Thomas Schofield, Charles F. Beyer, *C.E.,* Thomas Webster, *Q.C., and* Lavington E. Fletcher, *C.E.*

Since the first Report on the subject of "Steam-Boiler Legislation" was presented to the Meeting of the British Association, held last year at Liverpool, the Parliamentary Committee "appointed to inquire into the cause of Steam-Boiler Explosions and the best means of preventing them" have presented their Report.

The consideration of the result of the Parliamentary Committee's inquiry clearly becomes one of the most important duties in reporting to the British Association on "the various plans proposed for legislating on Steam-Boiler Explosions, with a view to their Prevention." Unfortunately, however, the Parliamentary Report has been so recently published that there has not been time for its due consideration, or for the Committee appointed to treat on this subject to meet and confer thereon. Under these circumstances it has been thought best not to attempt to enter upon the subject on the present occasion, but to postpone doing so until next year, after having an opportunity of watching the development of the measure, and its working when carried into actual practice; and therefore, in order that they might be in a position to report thereon to the next Meeting of the British Association, the Committee would beg to suggest their reappointment.

Report of the Committee on the "Treatment and Utilization of Sewage." Consisting of Richard B. Grantham, *C.E., F.G.S. (Chairman),* Professor D. T. Ansted, *F.R.S.,* Professor W. H. Corfield, *M.A., M.B.,* J. Bailey Denton, *C.E., F.G.S.,* Dr. W. H. Gilbert, *F.R.S.,* John Thornhill Harrison, *C.E.,* Thomas Hawksley, *C.E., F.G.S.,* W. Hope, *V.C.,* Lieut.-Col. Leach, *R.E.,* Dr. W. Odling, *F.R.S.,* Dr. A. Voelcker, *F.R.S.,* Professor A. W. Williamson, *F.R.S., F.C.S., and* Sir John Lubbock, *Bart., M.P., F.R.S. (Treasurer).*

The Committee, upon its reappointment at Liverpool last September (1870), proceeded at once to consider the subjects which seemed to demand immediate attention in furtherance of the investigation which had been again entrusted to it.

The first steps taken were to endeavour to procure information from the towns where works have been constructed for the application of sewage to land by irrigation, and from the places where the dry earth or Moule's system is in operation.

In order to commence the inquiry, a list of towns was prepared, to each of which a printed form of queries was sent; but only eight places have answered the circular on irrigation, and only one that relating to the dry-earth process. The answers from the towns have been tabulated, and the Table will be found at the end of this Report (Appendix A).

During the construction of the present tanks at Breton's Farm in the winter, very accurate observations could not at all times be made; but nevertheless, during the extreme frost, samples were taken of the sewage and of the effluent water. The temperature of both, and also the temperature of the

atmosphere, was observed. Similar observations were made at Croydon and Norwood (see Section I.).

The observations as to the quantity and quality of the sewage and effluent water have been continued at Breton's Farm, with slight interruptions, as stated above, from the Meeting of the British Association at Liverpool down to the present time. The results of the gaugings are recorded in the Tables which will be found in Section II. of this Report.

The Committee has visited several sewage-farms, and examined the various methods that are pursued at them with a view to determining the practical conditions upon which the success of sewage-farming depends. They have had samples of sewage and of effluent water collected, and have had analyses made of them, which latter, with the remarks of the Committee, will be found in Section III.

The phosphate process of Messrs. Forbes and Price has been also examined by a Member of the Committee, and a description of the process, with an analysis of the effluent water from this process, is given in Section IV.

Analyses of the soil which has passed once and twice through earth-closets have been furnished by another Member; and the manner in which this process is carried out at Lancaster, with the results attained there, is described in Section V.

An ox which had been fed for the previous 22 months entirely on sewage-grown produce was slaughtered on July 15th at Breton's Farm, and the carcass examined by Dr. Cobbold and Professors Marshall and Corfield, in the presence of several Members of the Committee, with a view to ascertain the presence or absence of Entozoa in any stage of their existence. The results of this examination, and Dr. Cobbold's report, will be found appended (Appendix B).

The attention of the Committee has been drawn to certain anomalies in the figures given in the list of rainfalls in the "Tabulation compiled from returns furnished by 200 towns selected for classification," at the end of last year's Report.

On referring to the original returns, it has been found that the figures given in the Table are correctly taken from them.

Section I.—*A Comparison of Results obtained in the purification of Sewage at three Irrigation Farms during the severe frost of last winter.*

1. Breton's Farm, near Romford.

The following analyses show the composition of average samples of sewage and effluent water collected on the farm on January 2nd; each sample was made by collecting five portions at different times, and mixing them in proportion to the flow at the time.

	Solid matter.				Chlorine.	Ammonia.		Nitrogen as nitrates and nitrites.
	In solution.		In suspension.					
	Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		Actual.	Albuminoid.	
Town sewage, temp. 46° F. (=7°·7 C.)	87·60	47·60	27·66	6·52	11·50	5·084	0·294	
Sewage from trough, temp. 46° F. (= 7°·7 C.)…………	98·20	50·80	8·05	1·60	11·999	5·628	0·524	
Effluent water from drains B and C, temp. 40°·5 F. (= 4°·7 C.)…………	66·60	47·40	……	……	8·15	0·143	0·059	1·208

The sewage, after passing through the tank and pump, contains more solid matters in solution but much less in suspension than the sewage as it comes from the town; the agitation causes some of the suspended matter to pass into solution; and it will be noticed that the amount of albuminoid ammonia in solution is nearly doubled, showing that a considerable amount of nitrogenous organic matter formerly in a state of suspension has been dissolved.

This sewage is very much stronger than the average summer sewage, which only contains from 2·5 to 4 parts of actual ammonia in 100,000; and so one would hardly expect it to be so satisfactorily purified (especially considering the extreme frost and the want of growth) as the sewage was during the summer.

Nevertheless the purification was very satisfactory indeed; for the effluent water only contained 0·143 of actual ammonia, instead of 5·628, while the albuminoid ammonia was reduced from 0·524 to 0·059.

From this we see that very little nitrogen passes away in the form of ammonia or of organic nitrogen, even in winter, when vegetation has least to do with the purification.

Some of it passes away, however, in the form of nitrates and nitrites; but the amount which is thus lost is very little greater in the winter than in the summer, being 1·208 part in winter and about 1·106 part in summer in 100,000 parts.

Thus it appears that, with an underdrained soil, the sewage being obliged to pass *through* several feet of soil before it escapes, (1) oxidation goes on in winter as well as in summer, and almost all nitrogen lost is lost in an oxidized and inoffensive form, and (2) this loss is very slightly greater in winter with a very strong sewage than in summer with a weaker one; so that sewaging in the winter would appear to entail no extra loss of manure.

2. Beddington Farm, Croydon.

Three samples of Croydon sewage, taken from Beddington Fields, 3rd January, 1871.

The analyses show that the sewage applied to this farm contained on January 3rd, 1871, just about the same quantity of ammonia as that applied to Breton's Farm on the day before.

	Solid matter.		Chlorine.	Ammonia.		Nitrogen as nitrates and nitrites.
	In suspension.	In solution.		Actual.	Albuminoid.	
From open drain near gas-works, direct from filters, before being applied to land	48·70	15·70	5·360	5·440	0·188	None.
Taken at crossing of the road near farm buildings	42·70	......	3·69	2·384	0·064	0·242
From the confluence of two outfalls	45·30	......	3·82	0·744	0·045	0·305

The effluent water contained 0·744 part of ammonia, or between five and six times as much as that at Breton's Farm; the albuminoid ammonia was less in actual amount in the effluent water; but the reduction was from 0·188 to 0·045, or to one fourth of the original amount; while in the last case it was from 0·524 to 0·059, or to between one eighth and one ninth of the original amount contained in the sewage as pumped on to the land. The nitrates and nitrites in the effluent water were in insignificant amount, thus

showing that the nitrogen that is lost on this farm is lost for the most part in the form in which it came on to the land, and that mere surface-action (which is relied upon here) is not sufficient to cause the oxidization of the ammonia and organic matters contained in the sewage. At the same time the amount of purification effected was certainly very considerable.

3. Norwood Farm.

Samples of sewage and effluent water collected from Norwood Fields on January 5th, 1871.

The sewage employed on this farm was very strong, containing as much as 7·42 parts of ammonia in the 100,000.

	Solid matter.				Chlorine.	Ammonia.		Nitrogen as nitrates and nitrites.
	In solution.		In suspension.					
	Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		Actual.	Albuminoid.	
Sewage, collected at 1.15 P.M., temp. 42° F. (=5°·5 C.)	71·70	28·40	37·20	14·84	Not determined.	7·42	0·264	
Effluent water, collected at 12.45 P.M., temp. 34° F. (=1°·1 C.)	92·30	29·40	0·82	0·62	17·38	2·056	0·060	0·961

It will be seen that more than two parts of actual ammonia escaped as such in the effluent water, while nearly one fourth of the albuminoid ammonia also escaped unaltered. At the same time a considerable amount of nitrogen was lost as nitrates and nitrites, showing that a certain amount of oxidizing action was going on.

Thus there was a considerable loss of nitrogen, both in its original forms and also as nitrates and nitrites.

It must be remembered that this sewage was very strong, and that in this, as in the other two cases, the samples were taken under the most disadvantageous conditions during a very severe frost, when growth was at its minimum.

The purification is in every case very considerable; but these comparative results speak volumes in favour of underdraining sewage-farms, and of so obliging all the sewage to pass *through* the soil.

Some interesting results were observed as regards the temperature of the sewage and effluent water.

At Breton's Farm in the winter the temperature of the sewage was 46° F., that of the effluent water 40° F. = 4°·4 C., a reduction of 5° or 6° only; while at Beddington Farm the temperature of the sewage was 42° F., and that of the effluent water 34° F. = 1°·1 C., a reduction of 8°.

Thus with percolation through the soil the reduction is during the winter much less than with surface-flow.

On the other hand, we have observed that sewage is always cooled (see Table, Section II.) during the hottest weeks in summer by percolation through the soil, and almost always heated (sometimes considerably so) by a surface-flow during the summer.

These results are favourable to percolation through the soil as opposed to mere surface-flow, both in summer and winter.

Percolation causes a considerable cooling in the summer, while in winter it does not cool the effluent water so much as surface-flow does.

SECTION II.—*Breton's Sewage Farm.*

Statement of Weekly Quantities of Sewage received on the Farm, of Diluted Sewage pumped on to the Land, and of Effluent Water received therefrom.

No.	Date (inclusive).	Average noon-day temperature.	Rainfall during week.	Quantity of sewage delivered to the tank from the town.	Average temperature thereof.	Quantity of effluent water returned from land.	Average temperature thereof.	Quantity of diluted sewage distributed on land.	Average temperature thereof.	Proportion of effluent water to sewage distributed.	Remarks.
	1870.	° F.	in.	galls.	° F.	galls.	° F.	galls.	° F.		
1.	June 12 to June 18	......	......	1,619,800	63	769,100	55	2,407,200	55	·319	
2.	June 19 to June 25	......	......	1,577,400	62	654,800	56	2,268,900	63	·289	
3.	June 26 to July 2	......	......	1,601,000	63	610,100	57	2,223,200	60	·274	
4.	July 3 to July 9	......	......	1,539,300	......	747,600	......	2,285,500	......	·327	Tank overflowed, July 9, 2250 galls.
5.	July 10 to July 16	73	0·29	1,675,700	65	760,500	59	2,341,100	66	·325	Effluent water run into river, 17,200 galls. " " pumped " 743,300 "
6.	July 17 to July 23	76	0·00	1,650,600	65	723,400	60	2,191,800	67	·326	Effluent water turned into river, 160,300 galls. " " pumped " 563,100 "
7.	July 24 to July 30	70	0·81	1,954,900	......	730,400	61	2,470,500	66	·296	Tank overflowed, 183,500 galls. Effluent water turned into river, 84,100 galls. " " pumped " 646,300 "
8.	July 31 to Aug. 6	71	0·71	2,555,000	......	936,000	64	2,656,300	67	·353	Tank overflowed, 300,000 galls. Effluent water run into river, 512,700 galls. " " pumped " 423,300 "
9.	Aug. 7 to Aug. 13	70	0·29	1,856,500	66	902,000	61	2,130,600	67	·423	Effluent water run into river, 622,500 galls. " " pumped " 279,500 "
10.	Aug. 14 to Aug. 20	68	0·02	1,960,000	66	765,600	61	2,204,000	65	·347	Effluent water run into river, 501,300 galls. " " pumped " 264,300 "

11.	Aug. 21 to Aug. 27	64	0·50	1,726,500	64	767,700	58	2,394,600	64	·321	Effluent water turned into river, 504,300 galls. ,, ,, pumped ,, 263,400 ,,
12.	Aug. 28 to Sept. 3	62	0·51	2,249,300	63	731,540	58	2,525,600	63	·289	Effluent water run into river, 418,340 galls. ,, ,, pumped ,, 313,200 ,,
13.	Sept. 4 to Sept. 10	63	1·15	2,340,500	62	831,600	58	2,523,500	62	·329	Effluent water run into river, 624,100 galls. ,, ,, pumped ,, 207,500 ,,
14.	Sept. 11 to Sept. 17	60	0·19	2,243,140	61	934,640	57	2,456,000	61	·381	Effluent water run into river, 751,760 galls. ,, ,, pumped ,, 182,880 ,,
15.	Sept. 18 to Sept. 24	64	0·00	2,440,200	62	697,208	57	2,605,800	62	·267	Effluent water run into river, 531,608 galls. ,, ,, pumped ,, 165,600 ,,
16.	Sept. 25 to Oct. 1	64	0·00	1,833,740	64	662,630	57	2,452,168	64	·270	Effluent water run into river, 79,200 galls. ,, ,, pumped ,, 583,430 ,,
17.	Oct. 2 to Oct. 8	66·5	0·12	2,203,800	63	652,500	57	2,442,100	62·5	·267	Effluent water run into river, 414,200 galls. ,, ,, pumped ,, 238,300 ,,
18.	Oct. 9 to Oct. 15	53·5	0·09	1,715,900	61	833,800	56	1,976,200	60	·422	Effluent water run into river, 573,200 galls. ,, ,, pumped ,, 260,600 ,,
19.	Oct. 16 to Oct. 22	55	1·11	2,333,600	58·5	1,225,500	54	2,551,300	57·5	·480	Tank overflowed, 102,800 galls. Effluent water run into river, 937,500 galls. ,, ,, pumped ,, 288,000 ,,
20.	Oct. 23 to Oct. 29	51	0·80	2,782,400	56	1,183,900	53	2,215,200	56	·534	Tank overflowed, 854,100 galls. Effluent water run into river, 916,100 galls. ,, ,, pumped ,, 267,800 ,,
21.	Oct. 30 to Nov. 5	51	0·76	2,715,400	55·5	1,302,100	52	2,259,000	55·5	·576	Tank overflowed, 712,300 galls. Effluent water turned into river, 1,012,700 galls. ,, ,, pumped ,, 289,400 ,,
22.	Nov. 6 to Nov. 12	42	0·00	1,808,300	54·5	1,173,700	51	1,960,500	54·5	·599	Tank overflowed, 113,100 galls. Effluent water run into river 908,400 galls. ,, ,, pumped ,, 265,300 ,,
23.	Nov. 13 to Nov. 19	38	0·16	1,409,520	52·5	1,056,960	49	1,642,640	51	·643	Portion only of town sewage received on farm. Effluent water run into river, 820,640 galls. ,, ,, pumped ,, 236,320 ,,
24.	Nov. 20 to Nov. 26	48·5	1·13	880,800 6 days only	53	1,104,500	48	1,157,200 6 days only	52	·955	Day-sewage only received on farm. Effluent water run into river, 828,100 galls. ,, ,, pumped ,, 276,400 ,,

Statement of Weekly Quantities of Sewage &c. (*continued*).

No.	Date (inclusive).	Average noon-day temperature.	Rainfall during week.	Quantity of sewage delivered to the tank from the town.	Average temperature thereof.	Quantity of effluent water returned from land.	Avera e temperature thereof.	Quantity of diluted sewage distributed on land.	Average temperature thereof.	Proportion of effluent water to sewage distributed.	Remarks.
		° F.	in.	galls.	° F.	galls.	° F.	galls.	° F.		
25.	1870. Nov. 27 to Dec. 3	41·5	0·02	577,600 6 days only	54	957,600	48	874,300 6 days only	51·5	1·095	Day-sewage only received on farm. Effluent water run into river, 660,900 galls. " " pumped " 296,700 "
26.	Dec. 4 to Dec. 10	34·5	0·58	864,100	50	856,600	46·5	1,098,100	49	·780	Day-sewage only received on farm. Effluent water run into river, 622,600 galls. " " pumped " 234,000 "
27.	Dec. 11 to Dec. 17	44	1·68	980,800	49·5	Not gauged	......	1,433,500	49	......	Day-sewage only received on farm. Effluent water pumped 452,700 galls.
28.	Dec. 18 to Dec. 24	35·5	0·14	956,845	49	Not gauged	45	1,318,245	48	......	Day-sewage only received on farm. Effluent water pumped, 361,400 galls.
29.	Dec. 25 to Dec. 31	28·5	0·20	293,200 3 days only	43	774,800	43	426,900 5 days only	43	1·815	Day-sewage only received on farm. Effluent water run into river, 641,100 galls. " " pumped " 133,700 "
30.	1871. Jan. 1 to Jan. 7	32·5	0·06	677,200	46	593,700	43	796,000	46	·746	Day-sewage only received on farm. Effluent water run into river, 474,900 galls. " " pumped " 118,800 "
31.	Jan. 8 to Jan. 14	35	0·04	601,200 6 days only	46	858,100	42	738,400	46	1·162	Day-sewage only received. Effluent water run into river, 720,900 galls. " " pumped " 137,200 "
32.	Jan. 15 to Jan. 21	38·5	1·16	1,042,800	45	Not gauged	......	1,086,400	44	......	Day-sewage only received. Effluent water pumped, 161,600 galls. Tank overflowed, 118,000 galls.
33.	Jan. 22 to Jan. 28.	32	0·13	926,200 6 days only	44·5	Not gauged	......	1,081,100	45	......	Day-sewage only received. Effluent water pumped, 154,900 galls.
34.	Jan. 29 to Feb. 4	36	0·27	925,100	45·5	851,900	41	1,029,000	46	·828	Day-sewage only received. Effluent water pumped, 119,900 galls. Tank overflowed, 16,000 galls.
35.	Feb. 5 to Feb. 11.	44	0·78	1,107,400	47	Not gauged	......	1,174,800	47	......	Day-sewage only received. Effluent water pumped, 83,400 galls. Tank overflowed, 16,000 galls.

36.	Feb. 12 to Feb. 18	47	0·00	971,100	48	Not gauged	......	1,123,700	48	......	Day-sewage only received. Effluent water pumped, 152,600 galls.
37.	Feb. 19 to Feb. 25	47	0·05	903,300	49	629,900	43	1,022,500	49	·616	Day-sewage only received. Effluent water pumped, 119,200 galls. " " into river, 510,700 "
38.	Feb. 26 to Mar. 4	48·5	0·03	309,900 3 days only	50	535,700	44·5	356,500 3 days only	50	1·503	Day-sewage only received. Effluent water pumped, 46,600 galls. " " into river, 489,100 "
39.	Mar. 5 to Mar. 11	51	0·38	Nil.	......	354,500	44	Nil.	......	......	Effluent water all run into river.
40.	Mar. 12 to Mar. 18	47	0·48	129,600 1 day only	50	313,700	44·5	137,000 1 day only	50	......	Day-sewage only received. Effluent water pumped, 7,400 galls. " " into river, 306,300 "
41.	Mar. 19 to Mar. 25	55	0·00	1,040,300	51	328,300	45	1,155,500	51	·284	Day-sewage only received. Effluent water pumped, 115,200 galls. " " into river, 213,100 "
42.	Mar. 26 to April 1	47	0·77	957,300	50·5	466,700	45·5	1,116,000	50·5	·417	Day-sewage only received. Effluent water pumped, 158,700 galls. " " into river, 308,000 "
43.	April 2 to April 8	47	0·00	1,073,200	51	521,700	45·5	1,160,000	51	·449	Day-sewage only received. Effluent water pumped, 86,800 galls. " " into river, 434,900 "
44.	April 9 to April 15	54·5	0·20	1,120,700	53·5	580,100	46	1,203,900	53·5	·482	Day-sewage only received. Effluent water pumped, 83,200 galls. " " into river, 496,900 "
45.	April 16 to April 22	54	1·30	1,511,600	52	Not gauged	......	1,479,100 6 days only	52	......	Both day and night sewage received on Farm from this date. Effluent water all run into river.
46.	April 23 to April 29	57	0·35	1,947,900	54	1,490,100	48	2,012,000 6 days only	56	·741	All effluent water run into river.
47.	April 30 to May 6	56·5	0·47	2,078,100 6 days only	54	1,161,600	49	1,955,000 6 days only	56	·594	All effluent water run into river.
48.	May 7 to May 13	54	0·15	2,008,700	54	882,700	49·5	2,034,900 6 days only	55	·404	All effluent water run into river.

Statement of Weekly Quantities of Sewage &c. (*continued*).

No.	Date (inclusive).	Average noon-day temperature.	Rainfall during week.	Quantity of sewage delivered to the tank from the town.	Average temperature thereof.	Quantity of effluent water returned from land.	Average temperature thereof.	Quantity of diluted sewage distributed on land.	Average temperature thereof.	Proportion of effluent water to sewage distributed.	Remarks.
	1871.	° F.	in.	galls.	° F.	galls.	° F.	galls.	° F.		
49.	May 14 to May 20	55	0·00	1,881,600	57	Not gauged	......	1,770,100 6 days	56	......	All effluent water run into river.
50.	May 21 to May 27	64·5	0·28	1,753,400	58	715,800	53	2,027,800	59	·353	Effluent water pumped, 363,100 galls. „ „ into river, 352,700 „
51.	May 28 to June 3	60	0·15	1,557,500	59	897,000	53·5	1,849,800 6 days	59	·485	Effluent water pumped, 309,400 galls. „ „ into river, 587,600 „ Sewage run on to fallow land and not pumped, 46,800 galls.
52.	June 4 to June 10	54·5	0·04	1,538,300	58	768,000	53	1,937,500 6 days	57	·396	Effluent water pumped, 544,000 galls. „ „ into river, 222,000 „ Sewage run on fallow land and not pumped, 162,000 galls.
53.	June 11 to June 17	66·5	0·95	1,812,400	60	726,800	55	2,053,200 6 days	61	·354	Effluent water pumped, 318,700 galls. „ „ into river, 408,100 „
54.	June 18 to June 24	62	1·44	2,117,800	59·5	870,700	56	1,824,000 6 days	60	·477	Effluent water pumped, 302,400 galls. „ „ into river, 568,300 „ Sewage run on fallow land and not pumped, 697,000 galls.
55.	June 25 to July 1	64	0·05	1,594,700	61	838,300	56	1,951,000 6 days	61·5	·429	Effluent water pumped, 423,400 galls. „ „ into river, 414,900 „
56.	July 2 to July 8	66·5	0·78	2,122,600	62	868,300	57	1,380,000 6 days	61·5	·629	Effluent water pumped, 289,400 galls. „ „ into river, 578,900 „ Sewage run on fallow land & not pumped, 1,015,000 galls.
57.	July 9 to July 15	68·5	1·07	1,943,700	62·5	848,800	57·5	1,997,500 6 days	62·5	·425	Effluent water pumped, 300,900 galls. „ „ into river, 547,900 „ Sewage run on fallow land, 240,000 galls.

Remarks on Results of Gaugings.—The whole of the gaugings taken from the 12th of June 1870 to the 15th of July 1871 (a period of 399 days) have been calculated and tabulated, with the following results:—

Town Sewage.—The sewage received on the farm from the town of Romford during the above period has been

85,999,445 gallons = 383,926 tons,

and the number of days on which it has been delivered is 373, giving an average quantity of

230,562 gallons = 1029 tons per day.

This quantity does not, however, represent the total discharge from the town of Romford, because, from the middle of November 1870 to the middle of April 1871, the day-sewage only was delivered on to the farm, the night-sewage being allowed to run on to the meadows at Wybridge between the farm and the town; and for sixteen days in February and March the whole of the sewage was so disposed of, and there are no means of estimating the quantity during this period.

Respective flow of Day- and Night-sewage.—Since the 15th of April last, the new tanks being completed, and the sewage, with a few exceptions, being received continuously on the farm, it has been possible to calculate the respective flow of sewage during the working hours of the day and during the remaining period, and the following are the figures:—

	gallons.		tons.
Day-sewage (average time 10 hours)....	139,153	=	621¼
Night-sewage (average time 14 hours) ..	143,645	=	641¼
Total........	282,798	=	1262½

The day-sewage is calculated on the basis of gaugings in the sewer during the working hours of the day; the night-sewage is obtained by calculating the difference of quantities in the tanks between the times of stopping the pump one day and starting the next, allowing for the effluent water entering the tanks in the meantime.

By equalizing the time of day- and night-sewage (12 hours each) and computing the quantities on the basis of the above figures, the following is the result:—

	gallons.		tons.
Day-sewage, 12 hours	163,329	=	729
Night-sewage, 12 hours	119,469	=	533½
	282,798	=	1262½

According to these latter figures the night-sewage would be to the day as 79 to 100, or the day to the night as 137 to 100.

It should be borne in mind that the night-sewage of Romford fluctuates very much, owing to the Brewery frequently sending down a large quantity of water after working hours; this is especially the case on Saturday nights, as a reference to the detailed records will show.

Diluted Sewage pumped.—The diluted sewage pumped includes, as was explained in the last Report, a certain amount of effluent water, which flows into the tanks, and is there mixed with the sewage as it comes from the town. The engine has worked 366 days during the above period; the average time

of working since April 15th was 10 hours per diem. The total quantity pumped has been

	gallons.		tons.
	96,944,653	=	432,788
Average per diem	264,876	=	1,182

Effluent Water discharged.—Owing to floods at the outlets of the pipes, the quantities of effluent water discharged could not always be gauged. On the 343 days during which the observations could be taken,

39,449,178 gallons=176,112 tons

were discharged, being

115,012 gallons=513½ tons per day.

Assuming this to be the average quantity for the whole period, the total quantity intercepted from the lower subsoil and discharged through the pipes would be

45,889,788 gallons=204,865 tons,

or 47·3 per cent. of the sewage pumped.

Rainfall.—The rainfall at Breton's during the total period of 399 days has been 22·64 inches, or on 121½ acres about 62¼ million gallons, equal to 277,900 tons, or 2287 tons per acre.

Temperatures.—It will be seen that the temperatures of sewage and effluent water have been very uniform as compared with that of the air, being lower during extreme heat and higher during extreme cold. This was very noticeable during the severe frost of last winter. In one week, when the mean *noon-day* temperature of the air was 28°·5, that of the sewage received, sewage pumped, and effluent water was 43°. The ranges of variation over the total period have been:—

Atmosphere	28·5°	to	76°	=	47·5°
Town-sewage	43	,,	66	=	23
Sewage pumped	43	,,	67	=	24
Effluent water	41	,,	64	=	23

A remarkable feature in the record of temperatures is the extremely slow rate at which the temperature of the effluent water fell, and the length of time which elapsed before it recovered again. The first week that the average temperature at noon fell below the freezing-point was the one ending 31st December, when the average temperature of the air was 28°·5 F., and that of the effluent water was 43°; and after this, although the former rose, the latter fell, so that in the week ending February 4th the average temperature of the air was 36°, and that of the effluent water 41°. The next week the temperature of the air was 44°, the second week 47°, and the third week 47°, yet it was not until the third week that the temperature of the effluent water recovered to 43°.

Section III.—(*a*) *Observations on the Sewage-Farm at Tunbridge Wells.*

Before describing the results of the investigation by the Committee, it is desirable to state that, in the selection of the land to be irrigated at Tunbridge Wells, it has been a *sine qua non* condition that it should be at such a level that the sewage should reach it by gravitation; and to this end two farms

have been laid out, one to the north and the other to the south of the town, and an outfall sewer made to each.

Underdrainage has not been uniformly adopted on both farms; but where it previously existed, a peculiar arrangement has been made for the reapplication of the drainage-water.

The distribution of the sewage is chiefly effected by what is known as the catchwater system, which is necessarily, under ordinary conditions, accompanied by an overflow, in preference to its application in smaller quantities, sufficient to satisfy the demands of vegetation and to wet the land thoroughly without any overflow; while the absence of storage-reservoirs necessitates the continuous application of the sewage to some parts of the land by night as well as by day.

The population of Tunbridge Wells is 19,410.

The total quantity of sewage discharged is 1,000,000 gallons per 24 hours, of which about 400,000 gallons are supplied to the northern farm, and about 600,000 gallons to the southern one.

The northern sewage is applied to 123 acres of land, which have cost £21,000, and the southern to 167 acres, which have cost £27,000.

To deliver the sewage from the two main outlets of the town to the land, culverts or conduits, with precipitating-tanks for the separation of the larger portions of the solid matter from the liquid, have been constructed in a very substantial manner. The delivering-conduits on the north, extending for a length of two miles with the precipitating-tanks, have cost £2587 13*s*. 1*d*., while those on the south (of which the length is three miles) have cost £5809 17*s*. 8*d*. The tanks on the north farm have cost £833 3*s*. 9*d*., those on the south £1188 5*s*. 1*d*.

Thus the total cost of *external* delivering works amounts to £10,418 19*s*. 7*d*., which, added to the cost of the land, will be £58,418 19*s*. 7*d*., or £201 8*s*. 11*d*. per acre.

The solid matter collected in the tanks is removed from time to time, and used on the farms as additional manure. The tanks are not covered; and there is consequently a strong smell in their proximity, which is not discoverable in any other part of the farms.

The sewage having been delivered on to the land, is conveyed from one part to another by open main carriers and iron pipes, the former following contour-lines, and the latter partaking of the nature of inverted siphons in order to cross existing valleys or hollows.

The cost of these *internal* works per acre has been—

	£	s.	d.	
For Carriers	£18	13	0	
Drain	3	12	0	
Iron pipes	4	6	0	
Grubbing and trenching	3	16	0	
Roads	6	7	6	
Wire fence	1	5	6	
Or in all	£38	0	0	per acre.
Or a total of	£239	8	11	per acre.

The soil of nearly the whole of the northern farm is of a stiff clayey character, manifestly requiring underdrainage. It had for the most part been drained by the late owners before the Commissioners of Tunbridge Wells purchased it; but owing to the work being done as ordinary farm-drainage

independently of surface preparation, it was soon found that the sewage descended to the drains so rapidly as to prevent its profitable distribution on the surface. It was stated to the Committee that when this effect was discovered it was determined that the drains should be stopped by digging down to them and plugging them, the result of which then was to keep the soil in a state of saturation, and to allow the unpurified sewage to pass over the surface into the stream. The engineer employed by the Commissioners has since superseded this state of things by adopting the special mode of treatment referred to, which consists of intercepting the existing drains at the depths at which they were originally laid, and bringing the underdrainage water to the surface by outlet drains discharging into lower carriers for redistribution.

At the time of the inspection by the Committee the lowest carriers were receiving effluent liquid of an impure character from the surface, at the same time that the underdrainage water was being discharged into them in the way described.

The land of the southern farm is not generally of so heavy a description as that of the northern, though portions of it contain clay. Other parts are peaty, and are naturally very poor. Wherever the engineer has considered it necessary to drain the subsoil, this has been effected in a manner similar to that adopted on the northern farm.

The striking features in the case of Tunbridge Wells are:—

1. Instead of concentrating the sewage at one farm under one management, it has been divided, in accordance with the watersheds, into two parts, involving two separate systems of works and management.

2. The main conduits and carriers are more than ordinarily substantial, and are therefore expensively constructed; and, following contour-lines on the surface, have a tortuous course, and so must interfere with approved cultivation.

3. The character of the underdrainage, being designed for the redelivery of the sewage on to a lower surface by drains gradually getting nearer and nearer to it, must necessarily prevent alike a frequent and deep working of the surface-soil.

4. The sewage being run over the surface of the land on the catchwater system (by night as well as day), with the intention of reapplying the overflow, its distribution is necessarily unequal both in quantity and quality, the first land sewaged receiving more than it requires, while the last must suffer from a deficiency unless there is a positive waste of sewage, as the analyses really show that there is.

These several features illustrate the advantage of combining with the services of the civil engineer and the chemist those of the practical agriculturist when laying out a sewage-farm. If they were not pointed out by the Committee thus early in the progress of sewage-irrigation, they might be a source of disappointment and surprise to those who contemplate the utilization of the sewage of their own towns by this the most profitable mode of treatment at present known, when properly conducted. While saying this, it is desirable to point out the superior character of the works carried out at Tunbridge Wells, and at the same time to express approval of the enterprising manner in which they have been undertaken by the Local Authority.

Remarks on the Analyses of the Sewage and Effluent Water from the Irrigation Farms at Tunbridge Wells.

North Farm.—In 100,000 parts. Samples taken in the proportion of $\frac{1}{1000}$ part of the flow per minute, by a measure graduated to $\frac{1}{100}$ of a gallon.

	Solid matter.				Chlorine.	Ammonia.				Nitrogen as nitrates and nitrites.
	In solution.		In suspension.			In solution.		In suspended matter.		
	Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		Actual.	Albuminoid.	Actual.	Albuminoid.	
Sewage from main sewer, collected July 4th & 5th, 1871 (average temp. 58°·5 F).	53·6	27·7	23·62	19·68	10·79	8·90	0·45	0·25	0·65	
Effluent water taken from 7 drains of Italian Rye-grass, and mixed 4th and 5th July (average temp. 57° F)....	41·8	29·7	......	......	6·96	1·34	0·09	......	......	trace.
Water from stream above the effluent drains on 6th July. (No sewage water had entered the stream for two days above the point where the samples were taken; average temp. 62° F)........	24·1	16·7	......	......	2·70	0·008	0·02	......	......	0·42

(Total nitrogen in effluent water 1·99.)

The sewage from the main, while containing a comparatively small amount of total solid matter in solution, contains a very large proportion of "actual" ammonia, and also of "albuminoid" ammonia, when both the suspended and dissolved matters are taken into account; it is a rich sewage whether the proportion of nitrogenous matters to the total solids or to the bulk of the sewage itself be considered. The chlorine is in fair average amount.

The analysis of the average effluent water shows that while the total solids are diminished in amount, the diminution is due to the retention by the soil and vegetation of the more volatile constituents, as the weight of ash left after ignition of the solid matters was greater in the case of the effluent water than in that of the sewage. This may be due to (1) concentration by the evaporation which takes place from the sewage of the soil and from the plants, or (2) to solution of salts already in the soil: that the latter cause is more probably the true one, we see from the diminished amount of chlorine, which, although it may not necessarily indicate dilution with ordinary subsoil water to a great extent, still would certainly not lead us to conclude that any concentration had taken place. That dilution with underdrainage water actually does take place has been already pointed out.

The amount of ammonia in the effluent water is too high, amounting to more than one seventh of that in the same volume of sewage, while albuminoid ammonia still remains to the extent of one fifth of the original amount; and the almost total absence of nitrates and nitrites in the effluent water shows the want of conditions favourable to oxidation; so that the purification of the sewage here, although considerable, is not so satisfactory as could be wished, or as might be effected by making filtration through the soil an essential feature in the process.

South Farm.—In 100,000 parts. Samples taken in the proportion of $\frac{1}{1000}$ part of the flow per minute, by a measure graduated to $\frac{1}{100}$ of a gallon.

	Solid matter.				Chlorine.	Ammonia.				Nitrogen as nitrates and nitrites.
	In solution.		In suspension.			In solution.		In suspended matter.		
	Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		Actual.	Albuminoid.	Actual.	Albuminoid.	
Sewage from main sewer at high rocks before entering the tanks on the 6th and 7th July, 1871 (temp. 62° F.),	44·40	26·90	19·54	7·30	9·48	7·20	0·75	0·00	0·40	
Effluent water from field of mangolds and two fields of meadow-land, all mixed, 7th and 8th July (average temperature 62°·5 F.)...	38·20	24·60	......	......	8·06	3·20	0·26	......	......	0·15
Water from the stream outside the farm-boundary above all the effluent drains, taken 8th July (temperature 63° F.) ...	18·60	12·40	......	......	2·62	0·008	0·016	......	......	trace

The results attained on the southern farm are, as shown by the above analyses, very unsatisfactory, and at the same time very reliable, as the slight diminution of the chlorine in the effluent water would lead us to believe that the loss of water due to evaporation had been about balanced by the influx of underdrainage water, so that no great amount, at any rate, of concentration had taken place.

We notice at once the large amount of "actual" and of "albuminoid" ammonia which escapes unoxidized in the effluent water. No less than four ninths of the "actual" ammonia and more than one third of the "albuminoid" ammonia, in the same volume of sewage, escapes in the effluent water, while the amount of nitrates and nitrites is very small; the effluent water is very impure indeed.

The analyses show distinctly that at these two farms, as at present man-

aged, more sewage is applied than can be purified by the surface-flow, even when that takes place through thick vegetation (as in the case of the samples from the fields of Italian rye-grass on the northern farm), and much more than can be purified under less advantageous conditions (as in the case of the samples from the field of mangolds on the southern farm, although the water from this field was mixed with that from two of meadow-land); and they show, too, that the valuable matters that are not utilized are not only thrown away, but are thrown away in their crude condition, not having been subjected to the oxidizing action necessary to convert them into innocuous nitrates and nitrites.

Lastly, we must notice the fact that the temperature of the effluent water of the northern farm is only slightly (less than one degree Fahr.) below that of the sewage, while the effluent water of the southern farm is actually half a degree Fahr. warmer than the sewage. This clearly shows that the sewage has not been subjected to the cooling which percolation through soil entails.

(b) *Observations on the Sewage-Farm at Earlswood designed for the Utilization of the Sewage of Red Hill and Reigate.*

This sewage-farm consists of about 70 acres of Earlswood Common, of which, it was stated, about 50 acres abutting on a tributary of the river Mole have been laid out for irrigation. It is intended very shortly to add more land to that already prepared from properties adjacent.

The soil is for the most part a clayey loam. The higher ground next the Common is rather freer in character, while the lower part appears to increase in density as it nears the outfall.

The surface, which has rather a steep fall in its higher part, gradually becomes more level as it descends, and has a very slight fall indeed as it approaches the outfall.

Before the sewage is delivered to the land for irrigation it passes through one of Latham's patent extractors, an ingenious invention for the separation of the solid from the liquid parts. The liquid sewage is delivered from the extractor by covered conduits, from which it is directed right and left into the highest carrier. The land laid out for irrigation is divided into three series of beds or slopes separated by roadways, on the upper side of each of which is a surface-drain to receive the effluent liquid as it passes off the beds above, and on the lower a main carrier to deliver the sewage for distribution to the series of beds below. The three series are divided rectangularly into nearly equal-sized blocks, to be again subdivided by minor or inner carriers, laid out partly on the catchwater and partly on the ridge-and-furrow form. The surface of the highest land of the uppermost series of beds is about 24 feet above the surface of the lowest land in proximity to the outfall-stream.

None of the land is underdrained, and the lowermost beds appear to be incapable of underdrainage at a sufficient depth unless the stream receiving the water to be discharged is appropriately deepened at very considerable cost.

In answer to inquiries, it was stated that after heavy rains the lowest portions of the irrigated lands are swamped by the backing of the water which collects on their surface when the soil itself is in a state of complete saturation. At the time of the inspection by the Committee (July 11th), the sewage had collected in pools on the surface of the irrigated beds in a manner injurious to the crop under treatment. The work of irrigation is designed so that the sewage applied to the higher land may be reapplied on the sur-

face of lower lands with a view to its further purification. The sewage as it passed off the first surface was observed to be far from clear to the eye, and it was not perfectly so when leaving the second surface. When it was ultimately discharged at the outfall it was still cloudy, but this was partly accounted for by the heavy rains of the previous day. The analyses of samples of effluent water taken at different points, hereafter referred to, will show the extent of purification effected.

Though the land had not been drained, it gave indications of a natural capability of drainage in the escape of the sewage from the sides of the carriers or drains, which are from 10 to 14 inches deep. The line of saturation was clearly shown in those shallow cuts to be nearly identical with their depth, and the liquid was seen oozing out of the land at some parts in a clarified condition, and at others accompanied by a slimy matter, some specimens of which have been microscopically examined by Mr. M. C. Cooke, M.A., whose report is here given.

Microscopical Examination of Slime and Mud from Bottom and Sides of Carriers at Earlswood Farm.

The fluid specimen of deposit sent to me for microscopical examination was the only one in a fit condition to report upon as to "the insects and animalculæ to be found therein." Obviously dried mud would give no satisfactory result as to living animals, since the majority of them would be dead and shrivelled beyond all power of determination.

I have examined the wet deposit by the aid of the microscope, and find it to contain a few Diatoms belonging to several genera and species, but in a comparatively small proportion to the volume of material. The Desmidiaceæ were also represented by a species of *Closterium*, of which I detected but a few individuals. Confervoid threads were also but sparingly scattered through the mass. Altogether there was a smaller percentage of unicellular Algæ than I expected to have found. Living vegetable matter was comparatively rare.

The animal inhabitants of the mud were numerous, especially of certain kinds. There were a few examples of that common Thysanurous insect, *Achorutes aquaticus,* sometimes so plentiful in the liquid draining from heaps of manure. The larvæ and pupæ of small Diptera I am unable to name in those stages, but their proportion was not large. Of *Euglena viridis* there was no lack; and any stagnant puddle, especially in the neighbourhood of farmyards, would have yielded an equal proportion. Infusorians were scarce; a few solitary individuals of *Vorticella microstoma,* and one or two specimens of *Paramecium,* were about all that I observed. But there was one group of animal organisms most abundantly represented, and these were the Annelids. When the mud was exposed to the light and sun, the surface became active with these creatures; about the diameter of a piece of cotton-thread, and from half an inch or less to nearly 2 inches in length, they wriggled over the whole surface. Some white, others pink, and a few of a deep blood-red were mingled together like eels, wriggling and scriggling in every drop that could be taken up and placed on a slide for examination. Skins without inhabitants were almost as plentiful; and it seemed to be impossible to get a drop of the material in the field of the microscope without either the worms themselves or empty skins.

(Signed) M. C. COOKE, M.A.

It appears to the Committee that the existence of the exuded matter described by Mr Cooke is mainly, if not wholly, due to the fact that the subsoil is kept in a saturated condition by the want of underdraining; and they desire to add their belief that with land thus saturated with sewage certain atmospheric conditions exist which may be attended by malaria more or less injurious to health. It need hardly be said that if the effluent liquid passing from a sewage-farm at a time when vegetation is in a luxuriant state, and when evaporation is more than ordinarily active (which was the case when

the Committee viewed the land), is not clear to the eye nor sufficiently pure to be admitted into rivers, there must be times when it may become exceedingly objectionable.

It is to be remarked in this case, moreover, that there was (on July 15th, 1871) more liquid passing off the land at the outfall than there was sewage delivered to it for application, due possibly to the passage of the recent rainfall through the porous soil of the higher part of the farm. This fact would, in the absence of the analyses of Dr. Russell, have led to the conclusion that the effluent liquid was purer than usual.

Observations on the Analyses of Sewage and Effluent Water from the Red Hill and Reigate Sewage-Farm.

In 100,000 parts. Samples taken 14th and 15th July, 1871, in the proportion of $\frac{1}{1000}$ part of the flow.

	Solid matter.				Chlorine.	Ammonia.				Nitrogen as nitrates and nitrites.	Total nitrogen.	
	In solution.		In suspension.			In solution.		In suspended matter.				
	Dried at 100° C.	After ignition.	Dried at 120° C.	After ignition.		Actual.	Albuminoid.	Actual.	Albuminoid.		In solution.	In suspended matter.
Sewage at the point where it enters the extractor. Average flow 130 gallons per minute (temperature 58° F.)	34·60	18·00	6·40	2·92	6·18	2·76	0·12	0·00	0·12			
Sewage after passing through the extractor and before application to land (temperature 58° F.)	33·00	17·50	4·16	2·04	6·04	2·55	0·14	0·00	0·09	......	2·91	0·03
Effluent water taken in twelve portions every two hours, after it had passed over one field of rye-grass (temperature 62°·5 F.)	29·40	17·80	......	......	4·40	1·32	0·06	......	......	0·08	1·55	
Effluent water taken in ten portions at the outfall, after it had passed over two fields of rye-grass. Average flow 152 gallons per minute (temperature 63° F.)	35·80	24·20	......	......	4·86	0·92	0·10	......	......	0·07	1·23	

This is decidedly a weak sewage, as it does not contain one third of the quantity of "actual" ammonia, nor one fourth of that of "albuminoid" ammonia that the samples of Tunbridge Wells (North Farm) contain; the

smaller amount of chlorine also shows this. The fact is, that a very large quantity of subsoil water is admitted into the sewers.

The effect of the "extractor" is to reduce the total suspended matters by slightly more than one third of their amount, the amount of solid matter in solution is slightly lessened, and a quarter of the nitrogenous organic matters in suspension pass into solution; these are effects not in any way due to the action of the machine except as an agitator.

The effect on this sewage of a flow over one field of rye-grass, as shown by the analysis of an average sample made by mixing twelve samples in the proportions indicated by the amount of flow at the time of collecting, was as follows:—

The suspended matters, being very small in amount, were not determined. The solid matters in solution were reduced in total amount, the reduction being chiefly due, as in the case of the Tunbridge-Wells farms, to the retention by the soil and plants of the more volatile substances, as the amount of solid matters left after ignition is practically the same in the effluent water as in the sewage. The lessening of the chlorine by more than one fourth of its original amount would point to the fact, already referred to, that a considerable amount of subsoil water dilutes the effluent water; but notwithstanding this dilution, the effluent water contains more than half as much "actual" ammonia as the same bulk of sewage (after passing through the extractor), and a quarter as much "albuminoid" ammonia, while the amount of nitrogen escaping as nitrates and nitrites is insignificant.

This effluent water is therefore not purified in a satisfactory way at all.

But the most interesting point about these analyses is the comparison of the effluent water which had passed over two fields of rye-grass with that which had only passed over one.

On a *primâ facie* view, it would have been expected that the former would have been much purer than the latter; but in this case, on the contrary, we find that the effluent water which has passed over two fields contains, in the same bulk,—

1. More than one fifth *more* solid matter in solution,
2. More than one third more fixed solids,
3. More "albuminoid" ammonia, viz. 0·10 instead of 0·06,
4. Rather more chlorine,
5. Very slightly less nitrogen as nitrates &c.,
6. More than one fourth less "actual" ammonia, than the effluent water which had passed over one field of rye-grass.

This shows us:—

1. That by passing over an additional field, the sewage has been strengthened instead of weakened, except as regards "actual" ammonia.

(That this strengthening is probably due chiefly to evaporation through the agency of the plants, is shown by the increase in albuminoid ammonia, and by the fact that the actual ammonia is the only constituent lessened in amount to any extent.)

2. That the nitrogenous organic matters, as shown by the amount of albuminoid ammonia, are increased.

3. That no additional oxidizing action took place. These results are what might have been anticipated from the description of the farm already given.

The soil, not being underdrained, is saturated with sewage, and the effluent water flowing off one field on to another, already saturated with sewage, can only concentrate itself by evaporation or by solution of matters in the upper layer of the soil.

There is this, then, against the catchwater-system, that if the fields are not underdrained the land will become saturated with sewage, and the effluent water will then pass off in an impure condition; and not only so, but the present example shows that after a second application the water may (except as regards actual ammonia) contain a greater amount of soluble impurities than it did before; and, above all, the nitrogenous organic matter (as indicated by the albumenoid ammonia) is not diminished, but rather increased, in spite of the active growth going on in the month of July.

The temperature of the effluent water from the first field was considerably ($4\frac{1}{2}$° Fahr.) *higher* than that of the sewage, and that from the second field half a degree higher than that from the first, a sufficient proof that percolation through the soil does not take place.

It may seem almost superfluous for the Committee, after so many years of general experience throughout the country, to argue in favour of the subsoil drainage of naturally heavy or naturally wet land with impervious subsoil for the purposes of ordinary agriculture; but some persons have strongly and repeatedly called in question the necessity of draining land when irrigated with sewage; and the two farms at Tunbridge Wells, to a great extent, and more especially the Reigate Farm at Earlswood, have been actually laid out for sewage-irrigation on what may be called the "saturation" principle; so that it appears to the Committee desirable to call attention to the fact, that if drainage is necessary where no water is artificially supplied to the soil, it cannot be *less* necessary after an addition to the rainfall of 100 or 200 per cent. But a comparison of the analyses of different samples of effluent waters which have been taken by the Committee from open ditches into which effluent water was overflowing off saturated land, and from subsoil-drains into which effluent water was intermittently percolating through several feet of soil, suggests grave doubts whether effluent water ought ever to be permitted to escape before it has percolated *through* the soil.

SECTION IV.—*The Phosphate Process.*

A Member of the Committee was present at an experiment which was performed with the phosphate process of Messrs. Forbes and Price at Tottenham on March 25th, 1871. His description of the experiment is as follows:—

The Tottenham sewage, after passing through some depositing tanks which had been constructed for the lime-process, was pumped up, at the rate of about 800 or 1000 gallons per minute (as stated), along a carrier into a tank 100 yards long and of gradually increasing breadth. This tank took three hours to fill.

As the sewage passed along the above mentioned carrier, the chemicals were mixed with it in the following way:—

Two boxes were placed over the carrier, one a few yards further along it than the other; the first contained the phosphate mixture, and the second milk of lime. Men were continually stirring the contents of each box, which were allowed to run continuously into the sewage as it passed underneath the boxes.

The phosphate mixture was stated to be made by powdering the native phosphate of alumina, mixing it with sulphuric acid in the proportion of a ton of phosphate to from 12 to 13 cwt. of the acid, and dissolving the mass in water.

The amount of the preparation added to the sewage was not ascertained, but it was stated to be certainly much less than the proportion indicated by previous experiments (1 ton of crude phosphate to 500,000 gallons of sewage).

The result of this addition was to deodorize the sewage to a very considerable extent indeed; and when some of it was placed in a precipitating glass, and allowed to stand, a speedy separation of the suspended matters took place.

The milk of lime is added to precipitate the excess of phosphate added, and just sufficient milk of lime is allowed to flow in to neutralize the sewage, the reaction of which to test-paper is observed from time to time after the addition of the milk of lime.

During the passage of the sewage thus treated through the large tank, the suspended matters were very completely deposited, and the supernatant water ran over the sloping edge of the tank at its extreme end bright and clear, and almost odourless.

Some of this water was collected, and was kept sealed up in a stone jar until July 24th, when it was analyzed by Dr. Russell, with the following result:—

Sample of Effluent Water taken from Tottenham Sewage, treated March 25th, 1871. Parts per 100,000.

Solid matter in solution.		Ammonia.		Chlorine.	Nitrogen and nitrates, &c.	Phosphoric acid.	Sulphuretted hydrogen.
Dried at 100° C.	After ignition.	Actual.	Albuminoid.				
99·00	76·30	5·17	0·16	8·45	None.	a trace	None.

It was found, after the lapse of four months, quite sweet and without smell. The suspended matter was in very small quantity, and consisted merely of a little whitish flocculent matter, doubtless lime due to the slight excess used on the day when the sample was collected. The water was quite clear, and only on looking through a considerable depth could a brownish tint be detected.

The analysis of it shows that it contains as much actual ammonia as ordinary dilute London sewage, and also a certain amount of albumenoid ammonia.

It contains *the merest trace* of phosphoric acid, as indicated by the molybdate-of-ammonia test, and no sulphuretted hydrogen, nor any nitrates or nitrites.

Some of the deposit had been taken out of the tank, and was drying in a shed, the water which separated from it forming little pools on the surface of the mass; both this water and the precipitate itself were free from all offensive smell.

It appears, then, that the suspended matters are entirely removed by this process, but the actual ammonia and, to a certain extent, the soluble organic matters are neither removed from the sewage nor oxidized; but an odourless precipitate is produced, which contains all the phosphate added, and contains it doubtless in the form of flocculent phosphate of alumina, the value of which, as a manure, is somewhat doubtful, being certainly not so great as the value of corresponding quantities of flocculent phosphate of lime.

The valuable constituents of sewage, with the exception of the suspended matter and the phosphoric acid, are not precipitated by this process, and cannot be utilized unless the effluent water be afterwards used for irrigation,

in which case the milk of lime would not be added, and the clarified sewage would still contain a quantity of phosphoric acid.

The advantage of this use of it, if it were found to answer from an economical point of view, would be the deodorization of the deposit in the tanks and of the sewage itself, which is certainly at present a great desideratum, especially as regards the tanks.

Section V.—*The Dry Earth System.*

The Committee did not consider that it was its duty to undertake the examination of every plan that might be proposed for the treatment or utilization of excretal matters, but only those which were already well before the public, and known, or supposed, to be affording something like satisfactory results. It had sent out forms of questions with a view of procuring information respecting the results obtained in the use of Moule's earth-closets, and there was every desire on the part of the Committee not to neglect the examination of any system which promised results satisfactory to the community.

Of eight forms of questions sent out relating to Moule's system, only one had been filled up and returned, and that one was from Lancaster. It appeared that about $2\frac{1}{2}$ lbs. of soil were used per head per day. The manure obtained is afterwards mixed with other town refuse, and the mixture is sold at 5*s.* a ton. The analysis of the manure published by the Rivers Pollution Commission showed, however, that it did not contain more nitrogen than good garden-mould. It was stated to have been applied at the rate of about 6 tons per acre to grass land; but the produce of hay was by no means large. It should be added, however, that even at Lancaster, the only place where an attempt has been made to carry out the system on a large scale, some of the conditions prescribed by Mr. Moule, and essential to its success as a means of avoiding nuisance and injury to health, are entirely neglected. Thus there is an average of twenty-four persons using each closet; and instead of any arrangement for the deposit of earth on the fæcal matters after every use of the closet, a quantity of soil is thrown once a day over the matters collected; and the result is, that the product is removed in a very offensive condition.

On behalf of the Committee, Dr. Gilbert has himself made some trials with Moule's earth system: 14 cwt. of air-dried and sifted clayey soil were set apart for the experiment. From one third to one half of the whole was used before it was necessary to empty the pit. When removed the mass appeared uniformly moist throughout, and (excepting in the case of the most recent portions near the surface) neither fæcal matter nor paper was observable in it; nor was the process of emptying accompanied by any offensive smell. After exposure and occasional turning over on the floor of a shed, the once-used soil was resifted, and again passed through the closet.

Below are given the percentages of moisture and of nitrogen in the soil under the various circumstances of the trial:—

	Before use.	After using once.	After using twice.
Percentage of moisture (at 100° C.) in air-dried and sifted soil	8·440	9·970	7·710
Percentage of nitrogen in air-dried and sifted soil	0·067	0·216	0·353
Percentage of nitrogen in soil dried at 100° C. ...	0·073	0·240	0·383

Calculated upon the air-dried condition, the increase in the percentage of

nitrogen was only about 0·15 each time the soil was used; and, even after using twice, the soil was not richer than good garden-mould. It is obvious, therefore, that such a manure, even if disposed of free of charge, would bear carriage to a very short distance only. It may be added that the percentage of nitrogen in the soil after using once, as given above, agrees very closely with that recorded in the report of the Rivers Pollution Commissioners, as found by them in the manure obtained, under professedly the same system, at Lancaster.

In conclusion, when it is borne in mind how small is the proportion of the nitrogen voided in the 24 hours that is contained in the fæces, how small is the proportion of the total urine that is passed at the same time, and how great is the dilution of the manurial matters by the amount of soil required, it is by no means surprising that the manure produced is of such small value as the results would show. It is obvious, too, that our domestic habits and practices would have to be entirely revolutionized to secure the collection and absorption of the whole of the urine, which contains by far the larger proportion of the valuable manurial matters voided. Moreover, assuming 2 or $2\frac{1}{2}$ lbs. of soil to be required for each use of the closet, if the whole of the liquid, as well as the solid excretal matters, were to be absorbed, there would probably be required from 9 to 10 lbs. of soil per head per day, or about $1\frac{1}{2}$ ton per head per annum. This, for London, taking the population at three and a quarter millions, would represent a requirement of about five million tons of soil per annum, or nearly 14,000 tons per day; and the quantity to be removed would, of course, be considerably greater. This illustration is sufficient to show the impracticability of any such system for large populations. Nevertheless it may readily be admitted that it would be of great advantage, in a sanitary point of view, in the cases of sick rooms, detached houses, or even villages, and that it might be even economical where the earth for preparation and absorption, and the land for utilization, are in close proximity.

APPENDIX B.

Report on the Post-mortem Examination of an Ox. *By* Dr. T. Spencer Cobbold, *F.R.S.*

Your Committee having invited me to examine the carcass of an ox fed for two years past on sewage-grown grass at Mr. Hope's farm near Romford, I have to report the perfect freedom of that animal from internal parasites of any kind.

I attribute this marked negative result to the following circumstances:—First, the animal did not graze on the farm, but was fed exclusively upon vegetable products cut and carried from the land. Secondly, the porous nature of the soil and subsoil alike would rapidly carry off the sewage, and thus ensure the passage of parasitic germs into the soil itself. Thirdly, I noticed on the irrigated portions of the farm a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers. Fourthly, the only mollusks I detected were examples of *Lymneus pereger*; these were obtained from a small pit of water to which the sewage had no access, and when examined after death were not found to contain any cercarian larvæ. Fifthly, the flaky vegetable tufts collected by me from the sides of the furrows occupied by sewage-currents consisted chiefly of *Batrachospermum moniliforme*, in the filaments of which were numerous active free nematodes, but no ova of any true entozoon. Sixthly, the sewage had a strong smell of beer, suggesting the presence of sufficient alcohol to

Tabular Statement of Information received relating to Sewage-irrigation [illegible]

Name of Town.	Population. Of [illegible]	Population. Contributing [illegible]	Average daily water-supply per head. From water-works.	Average daily water-supply per head. From other sources.	SEWAGE. Average daily discharge from town sewers.	Character or Quality. Area from which storm-water is discharged into sewers.	Character or Quality. Whether or not [illegible] water is admitted into sewers.	Character or Quality. Whether trades or [illegible] or slaughter houses discharge refuse into sewers.	On what terms disposed of by the town.	Whether applied to other lands along the course of the [illegible] on what terms.	Conveyance. How conveyed.	Conveyance. Distance conveyed.	Conveyance. Cost of conveyance.	Treatment. If strained or otherwise treated.	Treatment. If so, what is done with separated matter.	Application to Land. How applied.	Application to Land. [illegible]	Is any other manure than sewage [illegible] applied to land?	Disposal. Is all sewage-water supplied [illegible] in winter as well as in summer, night and day?	Disposal. What arrangements are made for disposal during frost?	Disposal. What is done with it [illegible] when the ground is saturated?	Disposal. Is [illegible] utilized?	Disposal. Average [illegible] to which sewage is applied daily.	LAND. Quantity [illegible]	Description of soil and subsoil, &c. and [illegible] laid out for drainage &c.	Describe drainage.	On what tenure held.	If [illegible]
			galls.	galls.	galls.	acres.																	acres.	acres				
[illegible]SHOT (Camp)	[illegible]	[illegible]	variable.	variable.	180,000 to 225,000	....	Not.	Slaughterhouse only.	....	Leased with the land.	By gravitation. Earthenware pipes.	2 miles	....	Strained, the coarser matter deposited in a settling tank.	Carted on to the land when dry.	By open channels.	....	Farm-yard manure, Superphosphate, potash, lime.	Yes ...	The sewage mostly runs over deeply ploughed land in winter.	Spread over a larger area.		$1\frac{1}{2}$ to 2	90........	Moor Land and gravel. A fall of 1 in 80 across the farm. Laid out in beds of ½ to 1 acre according to form and fall of surface.	From 4 to 6 feet deep where found necessary.	Lease for 16 years	Let [illegible]
[illegible]FORD.	16,437	16,437	....	....	657,000	Nil.	Admitted.	Not.	....	Not.	By gravitation-pipes.	....	Not ascertained.	Strained....	There is very little. It is used as manure.	....	....	No	Yes	None	Not provided for.	No	....	193	Loam, subsoil gravel. The land is favourable as regards levelling, which is being completed	Land drains to the outfall on the river.	Leasehold	Local[illegible]
CARLISLE	[illegible]	[illegible]	[illegible]		Not ascertained.	....	Admitted.	Cotton and woollen trades, dye-works, &c. All discharge into sewers.	Lease of 15 years, at a nominal rent of £5, the lessee being at all expense and risk.	Not.	Pumped up by steam-power.	....	Estimated at 40s. per acre.	Not........	....	....	....	No	Both winter and summer, but only in the daytime.	None	No difference made.	It disappears	2	110	4 to 6 feet of fine alluvial soil on a subsoil of open gravel. Levels uniform.	Naturally self-drained.	Lease 15 years, 11 expired.	Rent[illegible] of [illegible]
CHELTENHAM	40,000	Estimated, [illegible]	Abt. 15	uncertain.	About 1,0[illegible]	Not definitely known	Admitted by [illegible]	Slaughterhouses. There are but few manufactories.	Included in rent of land.	Yes, 200 acres. Owners pay 10s. per acre per annum, and prepare land themselves.	Sewer-pipes.	One sewer 3 miles, the other 1½ mile.	All the works cost £7,000.	Strained at tanks.	Sold at 2s. per cubic yard.	By overflowing the carriers.	....	No	Regularly applied without intermission.	Allowed to flow over land as usual, and is much purified.	Flows as usual. Land has good fall, and is seldom saturated.	Where convenient to do so.	Probably 10.	About 300 ..	Clayey. Surface undulating. Contour or catchwater carriers are formed in parts, in others ridges and furrows.	Usual system of pipe-drainage.	130 acres, freehold. About 200 acres belong to adjoining owners who pay for sewage.	Let [illegible]
[illegible]ROY[illegible]N [illegible]	[illegible]	[illegible]	50		3 to 13 months	1260	Admitted	Dye-works and slaughterhouses	Lease of 7 years to Company, who pay £3 per acre for land, and £7 per acre for sewage, with 5 per cent. on outlay on new works	[illegible] special terms.	Covered sewer and open canal.	510 yards		Strained by patent process.	Manufactured and sold.	Surface irrigation.		Portion of the manure produced on farm.	Yes	Applied to fallow land.	No difference made. Saturation of land considered an advantage.	Passed over successive areas until completely purified.	About one tenth of whole area.	400	Light and overlying gravel and clay.	By deep carriers. No subsoil drains.	Freehold and leasehold	Let [illegible]
CROYDON [illegible]	[illegible]	[illegible]	Water Co. 30	Local Bd. 56	[illegible] to 200,000	[illegible]	Admitted	Slaughterhouses &c.	Retained by town	Not	Brick sewer.			Filtered	Used on high land that is not irrigated.	By open and [illegible] covered carriers.		No	Yes	Applied to fallow and meadow land.	Passed on to land. Saturation aids purification.	Passed over successive areas until purified.	About one tenth of whole area.	60 ..	Stiff soil on brick earth.	Not drained. It was, but the drains were taken up, as the sewage passed into them unpurified.	Lease . .	Auth[illegible]
LEAMINGTON	20,917	20,917	15		800,000	1571	Admitted.	Slaughterhouses.	To Lord Warwick, at a rent of £450 per annum for 30 years	....	Pumped up through 18-in. iron pipes.	2½ miles....	Works £[illegible]	....	....	....	....	[Works not	completed.]	....	....	....	....	....	.... [Works not	completed.].	. .	
MERTHYR TYDFIL	[illegible]	[illegible] to 22,000	[illegible]	None.	In dry weather, 824,796	300	Not intentionally.	Slaughterhouses.	Retained by town.	Not.	....	....	....	Strained....	Mixed with town ashes.	....	.. (Works not yet	complete.	Portion of farm	only in operation.)			....	70 at present, 300 being acquired.	Loam, overlying gravel. Part level, part hilly.	Part underdrained	Part lease, part purchased.	Loc[illegible]

Name [illegible]	COST OF PREPARING LAND PER ACRE: Relative level of the sewage outfall and the point where sewage is received on land.	Machinery (if any).	Carriers.	Forming land for distribution of sewage over and above ordinary cultivation.	CROPS: Sewage applied. To what crops.	Average tons per acre applied to each crop.	Average produce per acre.	How disposed of.	EFFLUENT WATER: Quantity.	What becomes of it.	Total capital invested in the arrangements	Nett profit or loss per head of the population on the disposal of the sewage.	HEALTH: Is smell perceptible or disagreeable?	What has been the state of health of the cattle fed on the produce?	Has any disease been produced among labourers on the land that can be traced to the use of sewage?	Is the health of the inhabitants of the locality in any way affected	General advantages
ALD[illegible]	Sewage outfall is on the land.	No	information.		Grass, cabbages, rhubarb, French beans, asparagus, onions, leeks, violet, mint, Swedes, and turnips	Not registered.	Not recorded. Sold on ground.	Private sale.	Not known.	Runs into the Blackwater.			The sewage is 3 or 4 times as strong as ordinary town sewage, and the smell is perceptible in summer.	Very good.	No	No	Sanitary state of camp and barracks vastly improved. The land produces fair crops under sewage, which before produced nothing whatever
BEL[illegible]		Not	ascertained		Rye-grass and various root crops.	0000	Not recorded.	Public auction.	Not known.	Flows to river.		Not ascertained	Scarcely at any time. Imperceptible when crops are growing.	No complaints have reached the Board.	No	No.	
CAR[illegible]	12 feet below	say £250, [illegible] per yard		Nil.	Permanent grass.	Not ascertained.	....	All grazed by cattle and sheep.	Nil ..	There is none	£[illegible]0	..	No	Good	No	No	Land very much improved in value.
CHE[illegible] HA[illegible]	One outfall 12 feet above land, the other 30 feet.	....	Estimated at £2 10s. per acre.		Chiefly grass land	Cannot be stated accurately.	Not known; crops, partly grazed		Probably two thirds of the flow on to the land.	Passes off into brooks		Cannot be stated at present.	Scarcely, except in very hot weather.	Extremely good	None whatever.	No instance known.	The application of the sewage has enabled the authorities to purify the streams so as to remove all complaints. The yearly nett cost is much less than when disinfectants were used with very unsatisfactory results.
CRO[illegible]	A few feet above. ..		£2	£6	Rye-grass, rye, mangel, potatoes, carrots, parsnips, cabbages, broccoli, onions, celery, French beans, artichokes, &c	Varies considerably.	About £40 per acre all round, gross receipts.	Sold and consumed on farm.		Passed into the river Wandle.	About £8000, exclusive of land	Company makes a profit. Town gets the work done free of cost.	Not when solids are separated.	Good. When epidemics are rife, disease always takes mild form	None whatever.	Health of neighbourhood improved.	Greater certainty in the production of crops Larger yield of crops.
CRO[illegible]	Nearly level	....	£2	£15 ..	Rye-grass, man[illegible] cabbages, &c.	Varies	£27 per acre last year.	[illegible]		[illegible] passes to the river Ravensbourne	About £2,500	Total nett profit estimated at £170 last year.	Only when filters are foul.	Extremely good	None..........	Health of neighbourhood improved.	Greater certainty in the production of crops and larger yield of crops.
LEA[illegible]	Outfall 12½ feet below land.				The Local Board, has nothing to do with the farming, but has contracted to deliver the whole of the sewage of Leamington, as before stated.												
MER[illegible]	..... Outfall 3 feet above land	[illegible]...			Old turf and Italian rye-grass.	N[illegible]			N[illegible]	Flows into river . [illegible]	£30,000 borrowed.		No		None	No	

destroy the vitality of ordinary parasitic germs, though it was abundantly manifest that the free nematodes had suffered nothing in consequence.

As some guarantee for the efficient manner in which the carcass of the ox was examined, I may mention that the superficial muscles, with their associated areolar and aponeurotic coverings, were particularly investigated, portions of certain muscles, such as the scaleni and sterno-maxillaris, being dissected through and through. All the viscera were likewise scrutinized, especially the brain, lungs, liver, bladder, kidneys, paunch, reed, cæcum, and other natural divisions of the intestinal canal. The animal was not excessively fat, whilst its muscles were well developed and of a deep carneous lustre.

84 Wimpole Street, London, July 18, 1871. T. Spencer Cobbold, M.D., F.R.S.

Remarks by the Committee.

With regard to the examination of the carcass of the ox, which had been fed for twenty-two months on sewaged produce at Breton's Farm, those members of the Committee who were present and examined it with Dr. Cobbold concur in his statement as to its perfect *freedom from internal parasites of all kinds*; and they can also subscribe to most of his observations with regard to the possible reasons for this immunity. They wish especially to draw attention (1) to the fact, that on this farm there is "a remarkable absence of those molluscan and insect forms of life which frequently play the part of intermediary bearers" to entozoal larvæ: it would appear that the sewage drives these creatures away or kills them; and (2) to the composition of the "flaky vegetable tufts" collected from the sides of the carriers; these contained "numerous active free nematodes, but no ova of any true entozoon."

But the Committee cannot support the opinion expressed by Dr. Cobbold, that the strong smell of beer which the sewage had (caused of course merely by hop waste) would suggest "the presence of sufficient alcohol to destroy the vitality of ordinary parasitic germs," as the quantity of alcohol which would be necessary for this purpose in so large a bulk of sewage would be enormous, and especially as, as Dr. Cobbold says, "it was abundantly manifest that the free nematodes had suffered nothing in consequence."

It appears, then, that, as far as this one case goes (and it is certainly as conclusive as a single case could possibly be), there is no evidence that entozoal forms of life are to be found on the farm at all in any stage of their existence, or in the flesh of an animal fed exclusively for twenty-two months on sewaged produce grown on the farm.

Letters from M. Lavoisier *to* Dr. Black.

[Ordered by the General Committee to be printed in the Annual Report.]

Paris le 19 Septembre, 1789.

Monsieur,—C'est un membre de l'académie Royale des Sciences de Paris qui vous écrit à titre de Confrère: c'est un des plus zélés admirateurs de la profondeur de votre génie et des importantes révolutions que vos découvertes ont occasionnées dans les Sciences, qui profite, pour avoir l'honneur de vous écrire, de l'occasion de M. de Boullogne qui va finir son éducation à Edimbourg. Permettez-moi de vous le recommander. Il joint à d'heureuses dispositions un grand désir de s'instruire et il regarde comme un grand bonheur pour lui d'avoir une occasion pour se présenter à vous. Il a bien voulu, Monsieur, se charger de vous remettre un exemplaire d'un ouvrage que je viens de publier: vous y trouverez une partie des idées dont vous avez jetté

le premier germe: si vous avez la bonté de donner quelques instants à sa lecture, vous y trouverez le développement d'une Doctrine nouvelle que je crois plus simple et plus d'accord avec les faits que celle du Phlogistique. Ce n'est au surplus qu'en tremblant que je le soumets au premier de mes juges et à celui dont j'ambitionnerais le plus le suffrage.

J'ai l'honneur d'être très-respectueusement,
Monsieur,
Votre très-humble et très-obéissant Serviteur,

Paris, 24 Juillet, 1790.

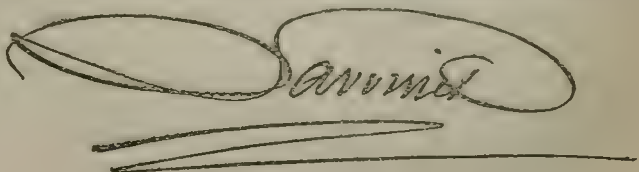
Monsieur,—J'apprends avec une joye inexprimable que vous voulez bien attacher quelque mérite aux idées que j'ai professé le premier contre la doctrine du phlogistique. Plus confiant dans vos idées que dans les miennes propres, accoutumé à vous regarder comme mon maitre, j'étois en défiance contre moi-même tant que je me suis écarté sans votre aveu de la route que vous avez si glorieusement suivie. Votre approbation, Monsieur, dissipe mes inquiétudes et me donne un nouveau courage.

Cette Lettre, Monsieur, vous sera remise par M. Terray intendant de Lyon neveu du Ministre des finances de ce même nom et mon parent; il conduit à Edimbourg son fils, jeune homme d'espérance et destiné a posséder une grande fortune, pour y finir son éducation et suivre les leçons des professeurs célèbres de l'université d'Edimbourg. Permettez-moi, Monsieur, de vous le recommander. L'intérêt que vous voudrez bien prendre à lui sera un premier titre qui l'annoncera d'une manière avantageuse et j'ai lieu de croire qu'il ne se rendra pas indigne de vos bontés.

Je ne serai pas content jusqu'à ce que les circonstances me permettent de vous aller porter moi-même le témoignage de mon admiration et de me ranger au nombre de vos disciples. La révolution qui s'opère en France devant naturellement rendre inutile une partie de ceux attachés à l'ancienne administration, il est possible que je jouisse de plus de liberté; et le premier usage que j'en ferai sera de voyager et de voyager surtout en Angleterre et à Edimbourg pour vous y voir, pour vous y entendre et profiter de vos lumières et de vos conseils.

J'ai commencé un grand nombre d'ouvrages et de travaux et j'aspire à un Etat de tranquillité qui me permette d'y mettre la dernière main.

J'ai l'honneur d'être très-respectueusement,
Monsieur,
Votre très-humble et très-obéissant Serviteur,



M. Black.

de l'académie des sciences.

Paris, le 19 Novembre, 1790.

M. Terray, Monsieur, m'a remis, en arrivant à Paris la lettre que vous m'avez fait l'honneur de m'écrire le 24 Octobre; il ne pouvait me faire un présent qui me fût plus agréable. J'ai cru que vous ne désapprouveriez pas que je la communiquasse à l'Académie des Sciences; elle n'a pas moins admiré l'élégance du style que la profondeur de philosophie et la candeur qui règne dans votre lettre, et elle a même désiré qu'elle fût déposée dans ses registres; mais je n'y ai consenti, qu'à condition qu'il m'en serait remis une copie certifiée du secrétaire. J'ai une autre grace à vous demander, mais sur laquelle je dois attendre votre aveu; c'est de vouloir bien me permettre d'en publier la traduction dans les Annales de Chimie.

M. Gillan a été témoin, depuis son séjour à Paris, de quelques expériences que j'ai faites sur la respiration et il a bien voulu y concourir. Nous nous sommes assurés des faits suivans:

1°. La quantité d'air vital ou gaz oxigène qu'un homme en repos et à jeun consomme, ou plutot convertit en air fixe ou acide carbonique, pendant une heure est de 1200 pouces cubiques de France environ, quand il est placé dans une température de 26 degrés.

2°. Cette quantité s'élève à 1400 pouces, dans les mêmes circonstances, si la personne est placée dans une température de 12 degrés seulement.

3°. La quantité de gaz oxigène consommée, ou convertie en acide carbonique, augmente pendant le tems de la digestion et s'élève à 1800 ou 1900 pouces.

4°. Par le mouvement et l'exercice on la porte jusqu'à 4000 pouces par heure et même davantage.

5°. La chaleur animale est constamment la même, dans tous ces cas.

6°. Les animaux peuvent vivre dans de l'air vital ou gaz oxigène, qui ne se renouvelle pas, aussi longtems que l'on le juge à propos, pourvu qu'on ait soin d'absorber, par de l'alcali caustique en liqueur, le gaz acide carbonique, à mesure qu'il se forme; en sorte que ce gaz n'a pas besoin, comme on le croyait, pour être salubre et propre à la respiration d'être mélangé avec une certaine portion de gaz azote ou Mophete.

7°. Les animaux ne paroissent pas souffrir dans un mélange de 15 parties de gaz azote et d'une partie de gaz oxigène, pourvu qu'on ait de même la précaution d'absorber le gaz acide carbonique, par le moyen de l'alcali caustique, à mesure qu'il est formé.

8°. La consommation du gaz oxigène et sa conversion en acide carbonique est la même dans le gaz oxigène pur et dans le gaz oxigène mêlé de gaz azote, en sorte que la respiration n'est nullement accélérée en raison de la pureté de l'air.

9°. Les animaux vivent assez longtems dans un mélange de deux parties de gaz inflammable et d'une de gaz oxigène.

10°. Le gaz azote ne sert absolument à rien dans l'acte de la respiration et il ressort du poumon en même quantité et qualité qu'il y est entré.

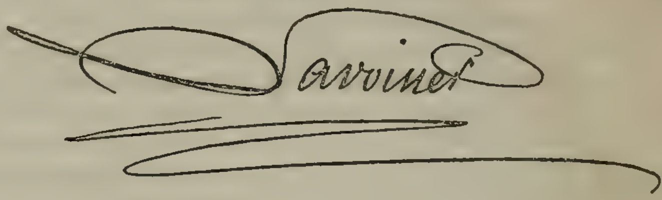
11°. Lorsque par l'exercice et le mouvement on augmente la consommation de gaz oxigène dans le poumon, la circulation s'accélère; ce dont il est facile de s'assurer par le battement du poulx: et en général lorsque la personne respire sans se gêner, la quantité de gaz oxigène consommée est proportionnelle à l'augmentation du nombre des pulsations multiplié par le nombre des inspirations.

Il est bien juste, Monsieur, que vous soyez un des premiers informés des progrès qui se font dans une carrière que vous avez ouverte, et dans laquelle

nous nous regardons tous comme vos disciples. Nous suivons les mêmes expériences, et j'aurai l'honneur de vous faire part de mes découvertes ultérieures.

J'ai l'honneur d'être avec un respectueux attachement, Monsieur,

Votre très-humble et très-obéissant Serviteur,



Report of the Committee, consisting of Dr. ANTON DOHRN, *Professor* ROLLESTON, *and* Mr. P. L. SCLATER, *appointed for the purpose of promoting the Foundation of Zoological Stations in different parts of the World:—Reporter,* Dr. DOHRN.

THE Committee beg to report that since the last Meeting of the British Association at Liverpool steps have been taken by Dr. Dohrn to secure the moral assistance of some other scientific bodies, and that the Academy of Belgium has passed a vote acknowledging the great value of the proposed Observatories. Besides this, the Government at Berlin has given instruction to the German Embassy at Florence and to the General Consul at Naples to do everything to secure success to Dr. Dohrn's enterprise. Next October the building at Naples will be commenced under the personal superintendence of Dr. Dohrn, who will be accompanied by the assistant architect of the Berlin Aquarium. The contractors agree to finish the building in one year, so that in January 1873 the Aquarium in Naples may be expected to be in working order.

The Naples Observatory being thus arranged for, the Committee beg leave to draw the attention of the British Association to the importance of establishing a Zoological Station in the British Islands, and to the opportunity which is now offered for such a proposition in consequence of the cessation of the grant to the Kew Observatory. In the same way as the Association took the initiative in the foundation of the Meteorological Observatories, so may they legitimately and with every prospect of success take in hand the foundation of Zoological Observatories. Until a recent date the Association has given considerable sums of money to dredging-explorations; but, in consequence of the advance of Zoological Science, some of the problems to be solved are so much changed and their nature is of such a character as to demand the assistance of the Association in other directions. The careful study of the development and the habits of marine animals can only be carried on by aid of large aquariums and cumbrous apparatus, which an individual could hardly provide for himself. This, and the copious supply of animals for observation, can be provided by such a cooperative institution. There can be little doubt of the convenience to naturalists, and of the permanent benefit to science, which would result from the foundation of a Zoological Station in the British Isles.

Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine. By JAMES DEWAR, *F.R.S.E.*

DURING the course of the last Meeting of the British Association, I took occasion to lay before the Chemical Section two short notes bearing directly on the subject of Thermal Equivalents; they were respectively entitled "Thermal Equivalents and Fermentation," and "Observations on the Oxides of Chlorine." In the first-mentioned communication it was proved that the decomposition of sugar into carbonic acid and alcohol was a reaction taking place without any great evolution of heat, if we accepted the thermal equivalent of sugar as determined by Frankland, along with the similar value of alcohol obtained from Favre and Silbermann's researches; and consequently the heat of fermentation must be derived from some other source than the sugar molecule itself,—the continued hydration of the alcohol produced, the secondary decompositions taking place, and the transformations of the ferment itself being the three available sources of supply.

The note on the oxides of chlorine had special reference to the heat evolved during the decomposition of these oxides. The researches of Favre and Silbermann having shown that the formation of hypochlorous acid and of chloric acid is attended with a large absorption of heat, it became interesting to ascertain if in this series of oxides we had a regular increment of absorption in passing from the lowest member of the series to the highest member, just as Andrews had found a similar relation to hold for certain oxides of the same metal, whose successive formation was attended with an evolution of heat. I suggested it would be interesting to make a complete examination of the thermal relations of these bodies along with the similar derivatives of bromine and iodine, and with this object in view I accepted a grant in order to prosecute these researches; and although my spare time has been variously occupied during the past year, I have found opportunity to make a considerable number of preliminary observations in connexion with this subject.

Heat absorbed during the Solution of Salts belonging to this Series per equivalent.

	Units.		Heat units.
KCl	4320	$KClO_3$	10,100
KBr............	4900	$KBrO_3$	9,680
KI	4800	KIO_3	5,300

Comparing the solution-values of chloride of potassium and bromide of potassium with the corresponding values obtained for the chlorate and bromate, the latter salts are observed to have a very much higher solution thermal equivalent; whereas, comparing iodide of potassium with iodate, we have only a slight increase in the latter salt. The highest absorption-values are therefore connected with the acids whose formation is attended with an absorption of heat. It will be interesting to find how these substances act with regard to the absorption of radiant heat, and if a similar relation is maintained.

The method I proposed to adopt in examining the thermal relation of the oxides of chlorine was based on the easy and rapid decomposition of dilute hydriodic acid, whose thermal equivalent in aqueous solution has been carefully determined. I soon found, however, chloric acid did not appreciably decompose dilute hydriodic acid when the strength of the respective acids in aqueous solution amounted to a half gramme equivalent per litre, nor did I

succeed better when I substituted hydrochloric acid for the hydriodic. A few experiments were made on the action of magnesium on chloric acid, with the view of ascertaining its thermal value from the oxidation of the nascent hydrogen; but, so far as my experiments extended, the results did not agree satisfactorily.

I had recourse then to the direct action of iodine on chloric acid, which I found acted easily on a solution of twice the normal strength, at a temperature of 80° C., although it did not act on a dilute aqueous solution in the cold. The reaction only taking place readily at a temperature of 80° C., complicates very much the mode of procedure, necessitating, as it does, a very constant temperature.

A series of observations gave as a mean 35,500 heat units evolved per equivalent of iodine acting on excess of chloric acid. This number represents the heat evolved in the transformation of chloric acid into iodic acid; and by subtracting from it the thermal value of the latter acid, we obtain the heat evolved from the decomposition of the chloric acid. The thermal value of iodic acid is very readily obtained through the reaction of dilute hydriodic acid, thus—

$$IO_5+5HI=5HO+6I,$$

which takes place with extreme rapidity in dilute solution, evolving 16,000 units per equivalent of hydriodic acid decomposed.

Assuming, then, the thermal value of hydrogen to be 34,000 units, and that of hydriodic acid to be 15,000, we obtain on calculation 15,000 units evolved during the formation of a molecule of iodic acid in aqueous solution. This number agrees very closely with that of A. Ditte's for the formation of iodic acid as found through the oxidation of phosphorus. Subtracting the number found for the formation of dilute iodic acid from the former number expressing the action of iodine on dilute chloric acid, we have the number 20,500 left for the thermal value of dilute chloric acid. Favre estimated the thermal value of dilute chloric acid as high as −65,234 per equivalent—this result being based on the action of chlorine on concentrated caustic potash, thus,

$$6KO+6Cl=5KCl+KClO_3,$$

and inserting in the equation the known values of oxide of potassium and chloride of potassium, and further correcting for dilution. It is obvious, however, where we have one atom of a compound formed for five atoms of another whose thermal value is not very accurately known, we multiply any error enormously.

In looking over Favre's original paper, in the 'Journal de Pharmacie' for 1853, on this subject, I observed that he mentioned a very curious observation with reference to the heat evolved during the saturation of hypochlorous acid with dilute oxide of potassium. He shows that an equivalent of caustic potash, when neutralized with an equivalent of hypochlorous, gives rise to an evolution of 10,768 heat units; but if two molecules of hypochlorous acid were employed per equivalent of caustic potash, he found an evolution of 22,114 heat units. The additional heat evolved is not due to the formation of an acid salt, because, on adding another atom of caustic potash, we obtain the normal amount of heat due to the saturation of the acid. It is reasonable to suppose, therefore, that the additional atom of hypochlorous acid induces the following reaction:—

$$3KO\,ClO=2KCl+KO\,ClO_5,$$

a decomposition that is well known to occur in certain conditions. Assuming this equation to be correct, and employing the following thermal numbers admitted by Favre—

Formation of	KO	$=$ 76,238	per equivalent.
„	KO with ClO	$=$ 10,678	„
„	KCl	$=$ 97,091	„
„	KO with ClO_5	$=$ 15,187	„
„	Cl with O	$=-$ 7,370	„
„	KO ClO condensing	$=$ 11,436	„

we obtain for the formation of an equivalent of aqueous chloric acid $-12,661$ heat units. This number is only about one-fifth part of the former number admitted by Favre.

There is yet another mode of arriving at the thermal value of chloric acid. Frankland recently made a series of observations on the heat evolved during the oxidation of many organic substances through the action of chlorate of potash, and had necessarily to deduce from the total heat evolved the heat due to the decomposition of the chlorate of potash employed; his highest result amounts to 5500 heat units evolved per equivalent of chlorate of potash decomposed. Now it is easy, from the admitted decomposition and with the aid of this result, to calculate the thermal value of chloric acid.

$$KO\,ClO_5 = KCl + O_6.$$

Formation of	KCl	$=101,000$
„	KO	$=76,238$
„	KO with ClO_5	$=15,187$
„	KO ClO_5 solution	$=10,100$

$$101,525 + X + 5500 = 101,016.$$

$X = -6009.$

The various determinations of the thermal value of chloric acid are inserted in the following Table, along with a reference to the reaction on which the determination is based:—

Action of chlorine on concentrated caustic potash	$=-65,234$ (Favre).
Condensation of hypochlorous acid	$=-12,661$ (Favre).
Decomposition of chlorate of potash	$=-$ 6,000 (Frankland).
Action of iodine on chloric acid	$=-20,500$ (Dewar).

The great difference in these results shows that even with the greatest care experimenters are apt to differ on the intricate subject of thermal values, and that before a satisfactory conclusion can be arrived at with reference to the true thermal value of chloric acid further experiments ought to be made.

A series of observations have been made on chlorous acid and on the peroxide of chlorine.

Chlorous acid was obtained by the action of benzol sulphuric acid on chlorate of potash, and after washing it was passed directly into water, in order to obtain a dilute solution.

The analysis of the solution has invariably differed from that of a solution of pure chlorous acid; and it seems absolutely necessary, in order to ensure

the purity of the aqueous solution, that the acid be previously liquefied, and its vapour passed slowly into water, as has been recommended by Brandeau. As the cold weather had all vanished before I could secure time to enter on this investigation, I saw it was hopeless to prepare the liquid acid readily and thus ensure a pure product, but made a few observations on the purest product I could obtain—the highest number I have obtained per equivalent of chlorous acid, ClO_3, acting on hydriodic acid amounting to 111,000 units, the following reaction taking place, thus,

$$ClO_3+4HI=HCl+3HO+I_4.$$

It is easy to calculate the heat absorbed during the formation of dilute chlorous acid, and it is found to amount to $-27,800$ heat units.

Similar observations have been made on peroxide of chlorine obtained from the action of oxalic acid on chlorate of potash. The aqueous solution of the gas has always contained appreciable quantities of free chlorine, and the value obtained will necessarily require some correction. One equivalent of ClO_4 acting on hydriodic acid evolves 120,000 heat units; the following reaction takes place:—

$$ClO_4+5HI=HCl+4HO+I_5.$$

When the requisite numbers are inserted in the above equation, the result is found to be 19,800 heat units absorbed for the formation of an equivalent of peroxide of chlorine.

The thermal values of chlorous acid and of peroxide of chlorine are likely to require considerable correction, because I have not found that strict uniformity in the results I should have liked. This is owing in great part to the difficulty of procuring a pure product, and the great tendency to secondary decomposition. The mode of conducting the experiments may also have considerable influence on the results. The above experiments were made with the relative proportions of the oxides of chlorine and of hydriodic acid that would completely neutralize each other, so as to precipitate the iodine in the free state. A series of experiments made in presence of excess of hydriodic acid, the requisite correction being made for the solution of the iodine, would be important, and these I intend to execute along with further observations on this subject.

The following observations have been made in connexion with this report:—

Action of dilute	HCl	on dilute	$HClO_3$	nothing
”	I	”	$HClO_3$	nothing
”	IO_5	”	H_2O	— 730
”	KHO	”	IO_5	15,000
”	I	”	$HClO_3$	36,500
”	HI	”	$HClO_3$	nothing
”	HI	”	HIO_5 (per eq. of HI)	16,000
”	ClO_3	”	HI (per eq. of ClO_3)	111,000
”	ClO_4	”	HI (per eq. of ClO_4)	120,000

Report on the practicability of establishing "A Close Time" for the protection of indigenous Animals. By a Committee, consisting of Prof. Newton, *M.A., F.R.S.,* Rev. H. B. Tristram, *F.R.S.,* J. E. Harting, *F.L.S., F.Z.S.,* Rev. H. Barnes, *and* H. E. Dresser (Reporter).

Your Committee has great pleasure in reporting that the object for which it was appointed has continued to excite attention in the public prints during the past year, and that in the direction indicated by its last Report—the protection, namely, of those birds generally coming under the term "Wild Fowl." There appears to be a widespread disposition among all classes to extend in their favour the provisions of the 'Sea-Birds' Preservation Act,' in proof of which your Committee may cite two facts :—1, the establishment in the county of Sussex (chiefly through the instrumentality of Mr. T. J. Monk, of Lewes) of an Association whose members pledge themselves to abstain from destroying Woodcocks in the breeding-season, which Association has met with great encouragement from the principal landed proprietors in the county ; and 2, the rapid growth of a well-founded belief that some steps are absolutely necessary to stop the netting or shooting of Plovers during the same season to ensure a continuance of the supply of their eggs, which form, as is well known, a valuable commodity.

Your Committee is fully aware of the danger of attempting to legislate on this subject before the proper time ; but from the assistance which has been promised in various influential quarters, it entertains a sanguine hope that some decided step may be taken next year ; and believing that the warmest supporters of the principle of establishing a Close Time for indigenous animals will readily listen to the recommendations of your Committee, it respectfully prays that your Committee may be reappointed.

Report of the Committee on Earthquakes in Scotland. The Committee consists of Dr. Bryce, *F.G.S.,* Sir W. Thomson, *F.R.S.,* D. Milne-Home, *F.R.S.E.,* P. Macfarlane, *and* J. Brough.

Very little worthy of record has occurred during the past year. There has been no earthquake or other disturbance in the Comrie district similar to those noticed in last Report. From other districts, however, slight shocks of earthquake have been reported—from Lochaber in the end of November and from the upper part of the Frith of Clyde in April. The latter occurred during the night, was noticed by few, and doubt has been expressed by some in regard to it. But as the same region was certainly agitated on more than one occasion during the conduct of the previous inquiry instituted by the Association, of which Dr. Buckland and Mr. Milne-Home had the charge, there is no improbability in such an occurrence ; very little information, however, that could be depended upon was obtained. In regard to the other earthquake-shock there is less doubt. The district in which it was felt comprises the Spean Valley and the lower part of the Great Glen, a region in which some of the most severe of our earthquakes have been from time to time experienced. In the present case, however, no change was produced on the surface, or in the position of objects (see Rep. by Mr. D. Milne-Home, Brit. Assoc. Rep. 1840) ; and without recording instruments

it has been found impossible to state, with any approach to certainty, whence the undulations emanated, or to estimate the intensity of the shocks. It is much to be desired that the additional duty of taking observations of this kind should be undertaken at such stations of the Scottish Meteorological Society as are situated in the districts where earthquakes have been so often experienced. Such a measure, however, would necessitate the adoption of a seismometer of a much simpler construction than that at Comrie, belonging to the Association—one which should occupy a small space, and be little liable to derangement, while capable of recording feeble shocks. Your Committee regrets that the hope expressed in last Report, in regard to the constructing of such an instrument, has not been realized; but they confidently hope that this important object will be accomplished in the course of the coming year. By permission of the Association, communications might then be opened with the Council of the Meteorological Society in regard to their placing such a seismometer at a number of their stations within the areas liable to disturbance, and establishing new stations with this express object where such do not now exist. Such a combined system of observations would bring the various areas into close relations with one another, and would possess every advantage over an inquiry limited to a single locality.

(Signed) James Bryce, M.A., LL.D.

Report on the best means of providing for a uniformity of Weights and Measures, with reference to the Interests of Science. By a Committee, consisting of Sir John Bowring, *F.R.S.*, The Right Hon. Sir C. B. Adderley, *M.P.*, Samuel Brown, *F.S.S.*, Dr. Farr, *F.R.S.*, Frank P. Fellowes, Professor Frankland, *F.R.S.*, Professor Hennessy, *F.R.S.*, James Heywood, *F.R.S.*, Sir Robert Kane, *F.R.S.*, Professor Leone Levi, *F.S.A.*, *F.S.S.*, C. W. Siemens, *F.R.S.*, Colonel Sykes, *F.R.S.*, *M.P.*, Professor A. W. Williamson, *F.R.S.*, James Yates, *F.R.S.*, Dr. George Glover, Sir Joseph Whitworth, *Bart.*, *F.R.S.*, J. R. Napier, H. Dircks, J. V. N. Bazalgette, W. Smith, Sir W. Fairbairn, *Bart.*, *F.R.S.*, *and* John Robinson:—Professor Leone Levi, *Secretary*.

Your Committee have much pleasure in reporting that the fifth and last Report of the Royal Commissioners to inquire into the condition of the Exchequer, now Board of Trade, Standards has now been published, and the general question of uniformity of weights and measures in this and other countries has thus been placed before Her Majesty's Government in all its bearings. Your Committee are much gratified at the large amount of information the Commissioners have collected on the progress of the Metric System in different countries, and only regret that they did not recommend a bolder course than the *permissive* legislation of its use. The Commissioners, it should be remembered, were not expressly instructed to inquire into the Metric System; but one of the points referred to them being to inquire and report whether *any* and *what* additions to the existing official Standards of Weights and Measures are now required, they understood that that involved expression of their opinion as to the establishment or continued prohi-

bition of the Metric System into this country, and they reported accordingly on the subject.

The Commissioners assumed that "there is no immediate cause requiring a general change in the existing system of legal weights and measures of the country for the purposes of internal trade," and regarded the question of introducing the Metric System only in the aspect of facilitating international trade and scientific researches; but your Committee are of opinion that in so doing the Commissioners have not sufficiently taken into account the bearings of the general question on education, on scientific workmanship, and on the general economics of the nation. The Royal Commissioners have recommended the legalization of the Metric System, and that, in order to facilitate the use of the same, Metric Standards accurately verified, in relation to the primary Metric Standards at Paris, should be deposited in the Standard Department of the Board of Trade. But although your Committee consider the carrying out of such recommendation a decided advance over the present anomalous state of the law, past experience leads them to fear that no general uniformity will ever be arrived at by merely *permissive* legislation, and that unless the use of Metric Weights and Measures is to become general at no distant period, the reform will have no fair chance of success. As the late Master of the Mint properly said, in the Standard Commission (Fifth Report, p. xxx), "Although the general introduction of Metric Weights and Measures for trade purposes might in the first instance be made *permissive* only, yet their *use* should, to some extent, be made *compulsory*, else the mere permission to use them in the home trade of this country would be practically a dead letter." Your Committee have already reported on the decided advantages of the Metric and Decimal system in economizing time and facilitating the teaching of arithmetic in the schools, in effecting mechanical valuations, and in Chemistry and Pharmacy. But neither of these advantages can be realized to the full extent until the new system of Weights and Measures, with its divisors and multiples, become identified with our ideas of dimensions and quantities. Your Committee admit that this must be the work of time; but all the more necessary is it to make provisions for the same, by inserting in any measure on the subject clauses fixing a time when the use of the new system will become binding. Your Committee therefore greatly regret that the Bill introduced in the House of Commons by Mr. J. B. Smith to establish the Metric System of Weights and Measures, and fixing a time when the use of the same shall become compulsory, has not received the cordial support it deserved. But a majority of five only against the Second Reading, in a small House, so late in the Session, must not be accepted as conclusive evidence of the deliberate opinion of the Legislature on the subject.

Pending the final settlement of this important question, your Committee are gratified in finding that, in consequence of representations made by them to the Right Hon. Mr. W. E. Forster, Vice-President of the Committee of Council on Education, the Educational Code of this year for the first time prescribes "that in all schools the children in Standards V. and VI. in Arithmetic should know the principles of the Metric System, and be able to explain the advantages to be gained from uniformity in the method of forming multiples and submultiples of the Unit." Your Committee are convinced that the School is the proper place for initiating this useful reform; and in view of the immense economy of time which would be gained in the teaching of arithmetic, your Committee would urge that teachers should at once commence introducing the subject in the Schools. To advance this desirable

object, your Committee have had a Conference at the Lecture Theatre of the Kensington Museum in June last, when valuable testimony was given of the progress made in instructing children on the subject in the United States by Prof. Nathaniel Allen, and in Bombay by Mr. T. B. Kirkham, both gentlemen connected with the Education Departments of the respective countries. Your Committee have forwarded copies of the resolutions passed at the Conference, with copy of a little treatise on the Theory and Practice of the Metric System, to the Head Master of every Public and Endowed School, and they are preparing to do the same to all the principal Elementary Schools in the Kingdom. It is much to be desired that all the works on arithmetic, and especially those which have acquired much reputation, should contain the necessary information on the Metric System, and your Committee are glad to report that this has already been done to a large extent. Your Committee have also represented to the London School Board the desirableness of introducing the Metric System in the Schools established or supported by the Board, and they have been informed that the subject will shortly be considered by Prof. Huxley's Committee. Your Committee will correspond in a similar manner with the other School Boards, and they trust that by these means they will secure the general teaching of the system.

Your Committee have forwarded a copy of the Mural Standard constructed by Casella to the Industrial Museum in Edinburgh, and they have also sent one to Newcastle. Your Committee have not yet been able to obtain the set of Metric Standards which they ordered, and they are glad to find from the following communication that the same will prove most useful for scientific researches:—

Pilton, Barnstaple,
July 27, 1871.

DEAR SIR,—I have been for some time conducting a series of observations on the specific gravity of minerals and rocks. As the greatest possible accuracy is indispensable, it is of course a matter of some importance that I should employ the weights which afford the most exact results. I find that calculations of this nature can be done with far more accuracy, and in about a quarter of the time, by using the Metric System; but although I have made numerous inquiries, I have hitherto failed in my endeavour to procure a verified set of Metric Weights. May I venture to suggest that it would very much tend to promote the object which the Committee of the British Association have in view if they would procure one or two sets of verified weights for the purpose to such Members as may require the use of such standards for scientific investigation, and thus afford them the means of comparing and verifying their own weights with the recognized standards of the Association.

I remain, dear Sir, yours faithfully,
Prof. Leone Levi. TOWNSHEND M. HALL.

Your Committee are convinced of the great utility of the suggestion; but they will require a larger grant, since, as will be seen in the Fifth Report of the Standard Commissioners, £50 was paid by that Commission for a set of Metric Standards made of brass by Deleuil, of Paris.

Your Committee regret that the war in France has suspended the operation of the International Standard Commission at Paris for the construction and verification of primary international Metric Standards. That movement arose from resolutions, expressing such a want, passed by the International Geodesical Conference held at Berlin in 1867, the Academy of Sciences of

St. Petersburg, and the Academy of Sciences in Paris; and we trust that by that means each country will possess a prototype copy of the Metre, made in relation to the Metre of the Archives in Paris, all the copies being made of the same material, compared by the same method and instruments, at the same temperature, and preserved in the same manner. Her Majesty's Government had deputed Prof. Airy, the lamented Prof. Miller, and Mr. Chisholm, the Wardens of the Standards, to attend the International Commission. Your Committee have reason to believe that it is of the utmost importance to continue to give to this question unremitting attention, and they are convinced that their action has been eminently useful in guiding the Legislature, both of this country, of the Colonies, and even of other countries, to the great question of uniformity of Weights and Measures and Coins in the interest of Science. In pursuance of this object, your Committee are anxious of diffusing as much information as possible. Especially they are desirous of supplying those who conduct scientific researches with the means of carrying them on in Metric Weights and Measures, as the most universally known, the most exact, and the most economical as regards time; for which purpose they would be glad to purchase one or two sets of Metric Standards. And for these, and other purposes, they suggest the reappointment of the Committee, with a grant of at least £75. The advantage of introducing a universal system of Weights and Measures is well admitted. Men of Science of all countries, to a large extent, use already a universal vocabulary in this respect; and your Committee trust that the British Empire will ere long throw on the side of such a reform the immense weight of her example and influence.

Report of the Committee appointed for the purpose of promoting the extension, improvement, and harmonic analysis of Tidal Observations. Consisting of Sir William Thomson, *LL.D., F.R.S.,* Prof. J. C. Adams, *F.R.S.,* J. Oldham, William Parkes, *M. Inst. C.E.,* Prof. Rankine, *LL.D., F.R.S.,* and Admiral Richards, *R.N., F.R.S.*

Report drawn up by Mr. E. Roberts.

82. The work performed for the Tide Committee since the last Meeting of the British Association has consisted chiefly in the evaluation of tide-components in a similar manner to that described in the previous Reports.

83. Mr. Parkes having again placed the tracings of the curves of the Kurrachee (Manora) self-registering tide-gauge at the disposal of the Committee, a second year's observations have been read off and completely reduced. In addition to the tide-components evaluated for Liverpool and Ramsgate, others (named for brevity J and Q) have been introduced to correct the lunar diurnal (declinational) tides for parallax. These components have been found to have sensible values for Kurrachee, where the diurnal tides are comparatively large. The solar elliptic semidiurnal (R and T) components have also been included, now that two complete years' observations were available. The whole of the values of these tide-components is contained in the previous Report (§ 67), the work having been completed before the Report was printed. The correcting of the calculated heights (§ 70) for these additional components will doubtless bring them still nearer

to the recorded high and low waters. It is contemplated correcting them before the printing of the Report, and if this is done, the results will be contained in it.

84. The comparison between the calculated and recorded heights for Liverpool (§ 68) not being considered as good as might have been expected from the labour bestowed on them, it was determined to continue the analysis of the Liverpool Tides, with the view, if possible, of detecting the cause of the largeness of some of the differences. Accordingly three years' observations in continuation of the year 1866–67 were read off and completely analyzed. The results are as follow, and the results of the previous years are also given for the sake of comparison:—

Year	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
	ft.	ft.	ft.	ft.	ft.	ft.	ft.
$A_0=$	16·7192	16·8208	16·8289	16·8998	17·0862	17·4877	17·1350
I* =	28°·5	27°·9	27°·0	18°·4	18°·4	19°·3	20°·6

Series S.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·0453	0·0696	0·0844	0·0470	0·0349	0·0399	0·0276
ϵ_1	69°·93	59°·78	56°·55	39°·04	66°·18	101°·28	124°·38
R_2	3·2149	3·3124	3·1938	3·1304	3·0990	3·1217	3·0516
ϵ_2	11°·78	11°·12	10°·08	11°·63	11°·31	11°·88	13°·63
R_4	0·0612	0·0600	0·0476	0·0475	0·0678	0·0640	0·0508
ϵ_4	322°·23	330°·18	294°·73	314°·32	327°·11	298°·49	312°·61

Series M.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·0192	0·0626	0·0092	0·0396	0·0194	0·0603	0·0841
ϵ_1	332°·19	266°·69	77°·27	358°·02	259°·28	322°·82	317°·18
R_2	9·6745	9·8124	9·8930	10·2713	10·2648	10·1210	10·1443
ϵ_2	326°·10	325°·45	323°·99	325°·55	326°·85	328°·38	329°·40
R_3	0·1053	0·0984	0·1525	0·0862	0·1022	0·1158	0·1014
ϵ_3	330°·60	315°·04	321°·71	335°·27	327°·43	324°·76	313°·23
R_4	0·6847	0·6573	0·6371	0·7648	0·7238	0·7018	0·7196
ϵ_4	220°·34	217°·68	221°·30	224°·19	222°·50	223°·68	227°·87
R_6	0·1812	0·1887	0·2093	0·2057	0·1936	0·1888	0·2200
ϵ_6	342°·76	348°·21	343°·17	343°·80	348°·52	353°·91	3°·47
R_8	0·0582	0·0808	0·0658	0·0667	0·0670	0·0665	0·0770
ϵ_8	262°·38	278°·17	259°·39	282°·09	280°·89	295°·60	293°·50

Series MS.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_4	0·4379	0·3488	0·3879	0·4635	0·4153	0·4080	0·3957
ϵ_4	270°·68	265°·86	270°·49	269°·45	271°·86	269°·15	272°·96

* I is the average inclination of the Moon's orbit to the Earth's equator, or the mean *maximum* declination, for the period.

Series K.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·3930	0·3978	0·3853	0·3278	0·2939	0·3116	0·3404
ϵ_1	283°·95	283°·08	273°·18	281°·60	285°·77	282°·71	285°·13
R_2	1·1850	1·2742	1·0995	0·6336	0·7701	0·7346	0·7882
ϵ_2	5°·98	0°·40	349°·61	9°·03	6°·63	359°·16	4°·25

Series O.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·4410	0·4136	0·4519	0·3058	0·2694	0·3374	0·3214
ϵ_1	316°·69	316°·28	318°·81	312°·74	312°·63	310°·88	307°·96

Series P.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_1	0·1250	0·1339	0·1306	0·1409	0·1357	0·1333	0·0935
ϵ_1	101°·96	105°·75	98°·61	88°·43	109°·17	84°·21	77°·08

Series L.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_2	0·5069	0·7849	0·3459	0·6015	0·5842	0·5129	0·4671
ϵ_2	157°·93	168°·91	144°·51	124°·08	151°·51	159°·39	151°·91

Series N.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_2	1·8608	1·7607	1·9716	2·1608	1·9124	1·8307	1·8917
ϵ_2	303°·52	308°·72	303°·98	301°·59	308°·14	307°·39	305°·06

	Series R.		Series T.	
	1857–58 & 1858–59.	1858–59 & 1859–60.	1857–58 & 1858–59.	1858–59 & 1859–60.
R_2	0·1006	0·0818	0·3490	0·1208
ϵ_2	146°·45	146°·60	67°·97	36°·78

Series λ.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_2	0·4091	0·2262	0·1165	0·2369	0·2166	0·1977	0·1913
ϵ_2	141°·68	134°·46	191°·08	175°·95	180°·68	138°·54	132°·16

Series ν.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_2	0·7423	0·6303	0·2841	0·7182	0·5051	0·1423	0·6912
ϵ_2	307°·91	284°·01	261°·09	278°·43	267°·42	311°·51	332°·41

Series μ.

	1857–58.	1858–59.	1859–60.	1866–67.	1867–68.	1868–69.	1869–70.
R_2	0·2860	0·2259	0·3076	0·2561	0·2278	0·2576	0·2303
ϵ_2	31°·72	42°·04	32°·55	32°·42	31°·94	64°·20	39°·64

85. It will be seen, on comparing the results contained in the previous Report with the above, that the chief tides (the lunar and solar semidiurnal) are now more retarded by about 4° than during the years previously analyzed. The calculated heights in the comparison should therefore more nearly represent the heights about eight minutes after the hours assigned to them. An examination of the differences will show this to be the case. A fresh calculation and due allowance made for atmospheric pressure would doubtless very considerably reduce the discrepancies.

86. The gradual increase in the height of the mean level of the water (A_0), probably arising from the filling in of the bed of the river and consequent increase of friction, will account for some portion of this increased retardation. There was a very violent rise in the mean level for the year 1868–69, amounting to four tenths of a foot; it, however, in the following year had again subsided to about its anticipated height. The uncertainty in the mean level of the water is an element which must at times seriously affect the differences between calculated and recorded heights in any method of computation of heights from a *fixed* datum. With respect to these changes now taking place in Liverpool Bay, the following extract contains the substance of the Marine Surveyor's report, dated October 2nd, 1871, and confirms the results determined by the preceding reductions:—

"The result of the survey of the channels of the river for the current year shows that the changes rendered necessary in the arrangements of the lighting and buoyage are more important in their immediate effect on the course of navigation than any which have occurred for some years. The present Queen Channel was opened in 1854, but was not buoyed for navigation purposes until two years afterwards. Since that time the process of advance from southward to northward of the Great Burbo Bank had been very gradual for the first ten years, but more rapid recently, so that the advance had extended to about half a mile. At the same time the North Channel had widened in the same proportion, and there was no appreciable narrowing of the channel in that direction. On the north side, however, during the last four years, the changes had been more rapid, and the buoys had been altered twice within that period. It was now necessary that the Bell Beacon should be removed northward one third of a mile, and also that the Formby light-ship should be removed one third of a mile westward. Thus the Bell Beacon buoy would be brought into a direct line with the Crosby light-ship. The bar was in a satisfactory state, and the whole of the channels were in as safe a condition as they had been for many years, being deeper as well as more straight and not narrower than formerly."

87. It is very much to be regretted that the authorities at Liverpool have chosen the George's landing-stage for a tide-float, affected as it must be (sometimes to a considerable extent) by the ever-varying weight it has to bear. This will affect the whole of the tide-components evaluated, but more especially the solar components, and will account for the different values of the solar semidiurnal tide, which, judging from the corresponding lunar component, should agree within much narrower limits. It is therefore thought that, should it be determined to again discuss the Liverpool tides, it will be better to take the tide-curves as self-registered at Helbre Island at the mouth of the Dee, in preference to those of George's Pier. The Helbre Island tide-curves it is considered will give much superior results.

88. Through the kindness of the United States' Coast Survey Office, two years' tide observations, taken at Fort Point, San Francisco Bay, California, being a continuation of the observations already analyzed (§ 66), have been

received. The results of the analysis of these observations (those contained in § 66 being also included for the sake of comparison) are as follow:—

Year	1858–59.	1859–60.	1860–61.
	ft.	ft.	ft.
A_0 =	8·7103	8·2651	8·1608
I =	28°·0	26°·9	25°·4

	Series S.			Series M.		
	1858–59.	1859–60.	1860–61.	1858–59.	1859–60.	1860–61.
R_1	0·0146	very small.	very small.	0·0539	0·0808	0·0863
ϵ_1	211°·96	......	......	46°·30	189°·37	32°·71
R_2	0·4067	0·3802	0·3824	1·6694	1·6215	1·6645
ϵ_2	334°·24	335°·80	336°·45	330°·81	331°·30	328°·72
R_3	......	......	......	very small.	very small.	very small.
ϵ_3	......	......	......	......	......	......
R_4	very small.	very small.	very small.	0·0616	0·0712	0·0698
ϵ_4	......	......	......	23°·32	26°·73	11°·15

Series MS.

	1858–59.	1859–60.	1860–61.
R_4	0·0248	0·0325	0·0315
ϵ_4	22°·33	12°·25	22°·81

Series K.

	1858–59.	1859–60.	1860–61.
R_1	1·3370	1·3036	1·2925
ϵ_1	196°·45	197°·43	196°·86
R_2	0·1759	0·1716	0·1351
ϵ_2	335°·21	327°·63	325°·37

	Series O.			Series P.		
	1858–59.	1859–60.	1860–61.	1858–59.	1859–60.	1860–61.
R_1	0·8917	0·8511	0·8784	0·3672	0·3659	0·3869
ϵ_1	357°·68	357°·52	352°·93	16°·52	15°·90	13°·52

	Series L.			Series N.		
	1858–59.	1859–60.	1860–61.	1858–59.	1859–60.	1860–61.
R_2	0·0591	0·0370	0·0506	0·3931	0·3494	0·3545
ϵ_2	102°·63	183°·00	170°·16	303°·46	305°·53	302°·51

	Series R.	Series T.
	1858–59 and 1859–60.	1858–59 and 1859–60.
R_2	0·0076	0·0142
ϵ_2	164°·00	277°·90

	Series λ.			Series ν.		
	1858–59.	1859–60.	1860–61.	1858–59.	1859–60.	1860–61.
R_2	0·0372	0·0275	0·0121	0·1044	0·0387	0·0437
ϵ_2	188°·30	156°·39	144°·18	287°·23	272°·46	349°·59

	Series μ.		
	1858–59.	1859–60.	1860–61.
R_2	0·0257	0·0311	0·0252
ϵ_2	254°·34	206°·14	209°·53

	Series J.			Series Q.		
	1858–59.	1859–60.	1860–61.	1858–59.	1859–60.	1860–61.
R_1	0·0819	0·0376	0·0565	0·1706	0·1056	0·1332
ϵ_1	213°·98	208°·29	183°·40	353°·03	331°·34	8°·93

89. Here again we have an abrupt diminution in the height of mean level for the first two years, which the following extract from a letter received from J. E. Hilgard, Esq., fully explains:—

"The change in the mean-level reading at Fort Point is a matter of much "annoyance to us. The tide-gauge was put up in a small building near the "end of a wharf, and the tide-staff used for comparison was close to it. Now "it was observed after the observations had continued some time that the "wharf was settling,—at least the part where the gauge stood. Then the "gauge was moved to a point a little nearer to the shore believed to be firm, "but we think the whole wharf settled and continued to do so for years. "There seems to be a bog formation underlying the surface deposit at that "place. There is probably no way of ascertaining the amount of settling "except from the observations themselves. We are now having frequent "levellings made, referring the tide-staff to a rocky ledge further inland."

It is contemplated including the new tide-components now evaluated in the calculation of the tide-heights shown in § 69, doubtless to their improvement.

90. It having come to the knowledge of the Tide Committee that the United States' Coast Survey Office was in possession of a series of hourly tide observations taken at Cat Island in the Gulf of Mexico, and which were of a very remarkable and interesting character, it was thought a favourable opportunity of testing the value of the harmonic analysis for the evaluation of the components of the tides of this place, which appeared very complicated and peculiar. Application having been made, a series of about thirteen months were received through the kindness of J. E. Hilgard, Esq. These are now in course of reduction.

The following results represent the tide-components as far as they have at present been evaluated. *Datum* 10 feet *below* datum of United States' Coast Survey:—

Year 1848. A_0=4·8574 ft. I=18°·45

	Series S.	Series M.	Series L.	Series N.
R_1	0·0442	0·0101	......	......
ϵ_1	10°·04	95°·21	......	......
R_2	0·0677	0·1195	0·0118	0·0269
ϵ_2	23°·80	10°·75	222°·40	33°·57

	Series K.	Series O.	Series P.	Series J.	Series Q.
R_1	0·4627	0·3855	0·1559	0·0292	0·0733
ϵ_1	55°·20	224°·29	230°·65	28°·22	215°·32
R_2	0·0205	......	......	......	......
ϵ_2	288°·73	......	......	......	......

Retardation of phase of Spring-tides 0d 12h 51m } after moon's syzygies.
Coincidence of phase of Declinational tides 0d 6h 15m } after moon's syzygies.

91. It is extremely interesting to find that, although the lunar and solar semidiurnal tides are very small in value. the series of means from which they were obtained were extremely regular and good, and the consequent determination of the phase of spring-tides from their respective epochs is probably correct within a few minutes. The proportion between the amplitudes of the lunar and solar semidiurnal tides is the nearest to equality yet obtained, being in the ratio of 11 to 6. The comparatively large value of R_1 of Series S is undoubtedly a genuine tide, but the smallness of the corresponding value of Series M must forbid the conclusion of its being purely astronomical. It is perhaps produced by temperature or wind, its time of maximum being about 40 minutes after noon. There are also indications of a similar and large annual tide of 0·3 foot amplitude, and maximum about July, which is also probably meteorological in its origin. The proportion between the lunar and solar diurnal (Declinational) tides (R_1 of Series O and P) will be, on the assumption of the variation of R_1 of Series O being as the square of the sine of the declination, about 4 to 1.

92. The following are the values of the long-period tides which have been obtained since the Edinburgh Meeting:—

	R	ε
	ft.	°
Solar annual tide (elliptic and meteorological) ...	0·274	144·50
Solar semiannual tide (declinational and meteorological)	0·128	35·02
Lunar monthly tide (elliptic)	0·106	304·17
Lunar fortnightly tide (declinational)	−0·043	136·69
Luni-solar fortnightly tide (synodic)	0·099	336·26

The above epoch for the solar annual tide would place the maximum about August 16.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Address by Professor P. G. Tait, *M.A., F.R.S.E., President of the Section.*

In opening the proceedings of this Section my immediate predecessors have exercised their ingenuity in presenting its widely differing component subjects from their several points of view, and in endeavouring to coordinate them. What they were obliged to leave unfinished, it would be absurd in me to attempt to complete. It would be impossible, also, in the limits of a brief address to give a detailed account of the recent progress of physical and mathematical knowledge. Such a work can only be produced by separate instalments, each written by a specialist, such as the admirable "Reports" which form from time to time the most valuable portions of our annual volume.

I shall therefore confine my remarks in the main to those two subjects, one in the mathematical, the other in the purely physical division of our work, which are comparatively familiar to myself. I wish, if possible, to induce, ere it be too late, native mathematicians to pay much more attention than they have yet paid to Hamilton's magnificent Calculus of Quaternions, and to call the particular notice of physicists to our President's grand Principle of Dissipation of Energy. I think that these are, at this moment, the most important because the most promising parts of our field.

If nothing more could be said for Quaternions than that they enable us to exhibit in a singularly compact and elegant form, whose meaning is obvious at a glance on account of the utter inartificiality of the method, results which in the ordinary Cartesian coordinates are of the utmost complexity, a very powerful argument for their use would be furnished. But it would be unjust to Quaternions to be content with such a statement; for we are fully entitled to say that in *all* cases, even in those to which the Cartesian methods seem specially adapted, they give as simple an expression as any other method; while in the great majority of cases they give a vastly simpler one. In the common methods a judicious choice of coordinates is often of immense importance in simplifying an investigation; in Quaternions there is usually *no choice*, for (except when they degrade to mere scalars) they are in general utterly independent of any particular directions in space, and select of themselves the most natural reference lines for each particular problem. This is easily illustrated by the most elementary instances, such as the following:— The general equation of Cones involves merely the *direction* of the vector of a point, while that of Surfaces of Revolution is a relation between the *lengths* of that vector and of its resolved part parallel to the axis; and Quaternions enable us by a mere

mark to separate the ideas of length and direction without introducing the cumbrous and clumsy square roots of sums of squares which are otherwise necessary.

But, as it seems to me that mathematical methods should be specially valued in this Section as regards their fitness for physical applications, what can possibly from that point of view be more important than Hamilton's ∇? Physical analogies have often been invoked to make intelligible various mathematical processes. Witness the case of Statical Electricity, wherein Thomson has, by the analogy of Heat-conduction, explained the meaning of various important theorems due to Green, Gauss, and others; and wherein Clerk-Maxwell has employed the properties of an imaginary incompressible liquid (devoid of inertia) to illustrate not merely these theorems, but even Thomson's Electrical Images. [In fact he has gone much further, having applied his analogy to the puzzling combinations presented by Electrodynamics.] There can be little doubt that these comparisons owe their birth to the small intelligibility, *per se*, of what has been called Laplace's Operator, $\frac{d^2}{dx^2}+\frac{d^2}{dy^2}+\frac{d^2}{dz^2}$, which appears alike in all theories of attraction at a distance, in the steady flow of heat in a conductor, and in the steady motion of incompressible fluids. But when we are taught to understand the operator itself we are able to dispense with these analogies, which, however valuable and beautiful, have certainly to be used with extreme caution, as tending very often to confuse and mislead. Now Laplace's operator is merely the negative of the *square* of Hamilton's ∇, which is perfectly intelligible in itself and in all its combinations; and can be defined as giving the vector-rate of most rapid increase of any scalar function to which it is applied—giving, for instance, the vector-force from a potential, the heat-flux from a distribution of temperature, &c. Very simple functions of the same operator give the rate of increase of a quantity in any assigned direction, the condensation and elementary rotation produced by given displacements of the parts of a system, &c. For instance, a very elementary application of ∇ to the theory of attraction enables us to put one of its fundamental principles in the following extremely suggestive form:—If the displacement or velocity of each particle of a medium represent in magnitude and direction the electric force at that particle, the corresponding statical distribution of electricity is proportional everywhere to the condensation thus produced. Again, Green's celebrated theorem is at once seen to be merely the well-known equation of continuity expressed for a heterogeneous fluid, whose density at every point is proportional to one electric potential, and its displacement or velocity proportional to and in the direction of the electric force due to another potential. But this is not the time to pursue such an inquiry, for it would lead me at once to discussions as to the possible nature of electric phenomena and of gravitation. I believe myself to be fully justified in saying that, were the theory of this operator thoroughly developed and generally known, the whole mathematical treatment of such physical questions as those just mentioned would undergo an immediate and enormous simplification; and this, in its turn, would be at once followed by a proportionately large extension of our knowledge*.

* The following extracts from letters of Sir W. R. Hamilton have a perfectly general application, so that I do not hesitate to publish them:—"De Morgan was the very *first* "person to *notice* the Quaternions *in print*; namely in a Paper on Triple Algebra, in the "Camb. Phil. Trans. of 1844. It was, I think, about that time, or not very long after- "wards, that he wrote to me, nearly as follows:—'I suspect, Hamilton, that you have "*caught the right sow by the ear!*' Between us, dear Mr. Tait, I think that *we* shall *begin* "the SHEARING of it!!" "You might without offence to me, consider that I abused the "license of *hope*, which may be indulged to an inventor, if I were to confess that I expect "the Quaternions to supply, hereafter, not merely *mathematical methods*, but also *phy-* "*sical suggestions*. And, in particular, you are quite welcome to smile if I say that it "does not seem extravagant to *me* to suppose that a *full* possession of those *à priori prin-* "*ciples* of mine, about the *multiplication of vectors* (including the Law of the Four Scales "and the conception of the Extra-spatial Unit), which have as yet been not much more "than *hinted* to the public, MIGHT have led (I do not at all mean that *in my hands* they "ever *would* have done so) to an ANTICIPATION of the great discovery of OERSTED."

"It appears to me that one, and not the least, of the services which quaternions may be "expected to do to mathematical analysis generally, is that their introduction will *compel*

And this is but *one* of the claims of Quaternions to the attention of physicists. When we come to the important questions of stress and strain in an elastic solid, we find again that all the elaborate and puzzling machinery of coordinates commonly employed can be at once comprehended and kept out of sight in a mere single symbol—a linear and vector function, which is self-conjugate if the strain be pure. This is simply, it appears to me, a proof either that the elaborate machinery ought never to have been introduced, or that its use was an indication of a comparatively savage state of mathematical civilization. In the motion of a rigid solid about a fixed point, a quaternion, represented by a single symbol which is a function of the time, gives us the operator which could bring the body by a single rotation from its initial position to its position at any assigned instant. In short, whenever with our usual means a result can be obtained in, or after much labour reduced to, a simple form, Quaternions will give it at once in that form; so that nothing is ever *lost* in point of simplicity. On the other hand, in numberless cases the Quaternion result is immeasurably simpler and more intelligible than any which can be obtained or even *expressed* by the usual methods. And it is not to be supposed that the modern Higher Algebra, which has done so much to simplify and extend the ordinary Cartesian methods, would be ignored by the general employment of Quaternions; on the contrary, Determinants, Invariants, &c. present themselves in almost every Quaternion solution, and in forms which have received the full benefit of that simplification which Quaternions generally produce. Comparing a Quaternion investigation, no matter in what department, with the equivalent Cartesian one, even when the latter has availed itself to the utmost of the improvements suggested by Higher Algebra, one can hardly help making the remark that they contrast even more strongly than the decimal notation with the binary scale or with the old Greek Arithmetic, or than the well-ordered subdivisions of the metrical system with the preposterous no-systems of Great Britain, a mere fragment of which (in the form of Tables of Weights and Measures) forms perhaps the most effective, if not the most ingenious, of the many instruments of torture employed in our elementary teaching.

It is true that, in the eyes of the pure mathematician, Quaternions have one grand and fatal defect. They cannot be applied to space of *n* dimensions, they are contented to deal with those poor three dimensions in which mere mortals are doomed to dwell, but which cannot bound the limitless aspirations of a Cayley or a Sylvester. From the physical point of view this, instead of a defect, is to be regarded as the greatest possible recommendation. It shows, in fact, Quaternions to be a special instrument so constructed for application to the *Actual* as to have thrown overboard everything which is not absolutely necessary, without the slightest consideration whether or no it was thereby being rendered useless for applications to the *Inconceivable.*

The late Sir John Herschel was one of the first to perceive the value of Quaternions; and there may be present some who remember him, at a British Association Meeting not long after their invention, characterizing them as a "Cornucopia from which, turn it how you will, something valuable is sure to fall." Is it not strange, to use no harsher word, that such a harvest has hitherto been left almost entirely to Hamilton himself? If but half a dozen tolerably good mathematicians, such as exist in scores in this country, were seriously to work at it, instead of spending (or rather wasting) their time, as so many who have the requisite leisure now do, in going over again what has been already done, or in working out mere details where a grand theory has been sketched, a very great immediate advance would be certain. From the majority of the papers in our few mathematical journals one would almost be led to fancy that British mathematicians have too much pride to use a simple method while an unnecessarily complex one can be

"those who adopt them (or even who admit that they *may* be reasonably adopted by other "persons) to consider, or to admit that others may usefully inquire, *what common grounds* "can be established for *conclusions common to quaternions* and to older branches of mathematics."

"*Could* any thing be simpler or more satisfactory? Don't you *feel*, as well as think, "that we are on a *right track*, and shall be *thanked* hereafter? Never mind when."

had. No more telling example of this could be wished for than the insane delusion under which they permit Euclid to be employed in our elementary teaching. They seem voluntarily to weight alike themselves and their pupils for the race; and a cynic might, perhaps without much injustice, say they do so that they may have mere self-imposed and avoidable difficulties to face instead of the new, real, and dreaded ones (belonging to regions hitherto unpenetrated) with which Quaternions would too soon enable them to come into contact. But this game will certainly end in disaster. As surely as Mathematics came to a relative stand-still in this country for nearly a century after Newton, so surely will it do so again if we leave our eager and watchful rivals abroad to take the initiative in developing the grand method of Hamilton. And it is not alone French and Germans whom we have now to dread, Russia, America, regenerated Italy, and other nations are all fairly entered for the contest.

The flights of the imagination which occur to the pure mathematician are in general so much better described in his formulæ than in words, that it is not remarkable to find the subject treated by outsiders as something essentially cold and uninteresting, while even the most abstruse branches of physics, as yet totally incapable of being popularized, attract the attention of the uninitiated. The reason may perhaps be sought in the fact that, while perhaps the only successful attempt to invest mathematical reasoning with a halo of glory—that made in this Section by Prof. Sylvester—is known to a comparative few, several of the highest problems of physics are connected with those simple observations which are possible to the many. The smell of lightning has been observed for thousands of years, it required the sagacity of Schönbein to trace it to the formation of Ozone. Not to speak of the (probably fabulous) apple of Newton, what enormous consequences did he obtain by passing light through a mere wedge of glass, and by simply laying a lens on a flat plate! The patching of a trumpery model led Watt to his magnificent inventions. As children at the sea-shore playing with a "roaring buckie," or in later life lazily puffing out rings of tobacco-smoke, we are illustrating two of the splendid researches of Helmholtz. And our President, by the bold, because simple, use of reaction instead of action, has eclipsed even his former services to the Submarine Telegraph, and given it powers which but a few years ago would have been deemed unattainable.

In experimental Physics our case is not hopeless, perhaps not as yet even alarming. Still something of the same kind may be said in this as in pure Mathematics. If Thomson's Theory of Dissipation, for instance, be not speedily developed in this country, we shall soon learn its consequences from abroad. The grand test of our science, the proof of its being a reality and not a mere inventing of new terms and squabbling as to what they shall mean, is that it is ever advancing. There is no standing still; there is no running round and round as in a beaten donkey-track, coming back at the end of a century or so into the old positions, and fighting the self-same battles under slightly different banners, which is merely another form of stagnation (Kinetic Stability in fact). "A little folding of the hands to sleep," in chuckling satisfaction at what has been achieved of late years by our great experimenters, and we shall be left hopelessly behind. The sad fate of Newton's successors ought ever to be a warning to us. Trusting to what he had done, they allowed mathematical science almost to die out in this country, at least as compared with its immense progress in Germany and France. It required the united exertions of the late Sir J. Herschel and many others to render possible in these islands a Boole and a Hamilton. If the successors of Davy and Faraday pause to ponder even on *their* achievements, we shall soon be again in the same state of ignominious inferiority. Who will then step in to save us?

Even as it is, though we have among us many names quite as justly great as any that our rivals can produce, we have also (even in our educated classes) such an immense amount of ignorance and consequent credulity, that it seems matter for surprise that true science is able to exist. Spiritualists, Circle-squarers, Perpetual-motionists, Believers that the earth is flat and that the moon has no rotation, swarm about us. They certainly multiply much faster than do genuine men of science. This is characteristic of all inferior races, but it is consolatory to remember that in spite of it these soon become extinct. Your quack has his little

day, and disappears except to the antiquary. But in science nothing of value can ever be lost; it is certain to become a stepping-stone on the way to further truth. Still, when our stepping-stones are laid, we should not wait till others employ them. "Gentlemen of the Guard be kind enough to fire first" is a courtesy entirely out of date; with the weapons of the present day it would be simply suicide.

There is another point which should not be omitted in an address like this. For obvious reasons I must speak of the general question only, not venturing on examples, though I could give many telling ones. Even among our greatest men of science in this country there is comparatively little knowledge of what has been already achieved, except of course in the one or more special departments cultivated by each individual. There can be little doubt that one cause at least of this is to be sought in the extremely meagre interest which our statesmen, as a rule, take in scientific progress. While abroad we find half a dozen professors teaching parts of the same subject in one University (each having therefore reasonable leisure), with us one man has to do the whole, and to endeavour as he best can to make something out of his very few spare moments. Along with this, and in great part due to it, there is often found a proneness to believe that what seems evident to the thinker cannot but have been long known to others. Thus the credit of many valuable discoveries is lost to Britain because her philosophers, having no time to spare, do not know that they are discoveries. The scientific men of other nations are, as a rule, better informed [certainly far better encouraged and less over-worked], and perhaps likewise are not so much given to self-depreciation. Until something resembling the 'Fortschritte der Physik,' but in an improved form, and published at smaller intervals and with much less delay, is established in this country, there is little hope of improvement in this respect. Why should science be imperfectly summarized in little haphazard scraps here and there, when mere property has its elaborate series of Money-articles and exact Broker's Share-lists? Such a work would be very easy of accomplishment: we have only to begin boldly; we do not need to go back, for in every year good work is being done at almost every part of the boundary between, as it were, the cultivated land and the still unpenetrated forest—enough at all events to show with all necessary accuracy whereabouts that boundary lies.

There is no need of entering here on the question of Conservation of Energy; it is thoroughly accepted by scientific men, and has revolutionized the greater part of Physics. The facts as to its history also are generally agreed upon, but differences of a formidable kind exist as to the deductions to be drawn from them. These are matters, however, which will be more easily disposed of thirty years hence than now. The Transformation of Energy is also generally accepted, and, in fact, under various unsatisfactory names was almost popularly known before the Conservation of Energy was known in its entirety to more than a very few. But the Dissipation of Energy is by no means well known, and many of the results of its legitimate application have been received with doubt, sometimes even with attempted ridicule. Yet it appears to be at the present moment by far the most promising and fertile portion of Natural Philosophy, having obvious applications of which as yet only a small percentage appear to have been made. Some, indeed, were made before the enunciation of the Principle, and have since been recognized as instances of it. Of such we have good examples in Fourier's great work on Heat-conduction, in the optical theorem that an image can never be brighter than the object, in Gauss's mode of investigating electrical distribution, and in some of Thomson's theorems as to the energy of an electromagnetic field. But its discoverer has, so far as I know, as yet confined himself in its explicit application to questions of Heat-conduction and Restoration of Energy, Geological Time, the Earth's Rotation, and such like. Unfortunately his long-expected Rede Lecture has not yet been published, and its contents (save to those who were fortunate enough to hear it) are still almost entirely unknown.

But there can be little question that the Principle contains implicitly the whole theory of Thermo-electricity, of Chemical Combination, of Allotropy, of Fluorescence, &c., and perhaps even of matters of a higher order than common physics and chemistry. In Astronomy it leads us to the grand question of the *age*, or

perhaps more correctly the *phase of life*, of a star or nebula, shows us the material of potential suns, other suns in the process of formation, in vigorous youth, and in every stage of slowly protracted decay. It leads us to look on each planet and satellite as having been at one time a tiny sun, a member of some binary or multiple group, and even now (when almost deprived, at least at its surface, of its original energy) presenting an endless variety of subjects for the application of its methods. It leads us forward in thought to the far-distant time when the materials of the present stellar system shall have lost all but their mutual potential energy, but shall in virtue of it form the materials of future larger suns with their attendant planets. Finally, as it alone is able to lead us, by sure steps of deductive reasoning, to the necessary future of the universe—necessary, that is, if physical laws for ever remain unchanged—so it enables us distinctly to say that the present order of things has *not* been evolved through infinite past time by the agency of laws now at work, but must have had a distinctive beginning, a state beyond which we are totally unable to penetrate, a state, in fact, which must have been produced by other than the now acting causes.

Thus also, it is possible that in Physiology it may, ere long, lead to results of a different and much higher order of novelty and interest than those yet obtained, immensely valuable though they certainly are.

It was a grand step in science which showed that just as the consumption of fuel is necessary to the working of a steam-engine, or to the steady light of a candle, so the living engine requires food to supply its expenditure in the forms of muscular work and animal heat. Still grander was Rumford's early anticipation that the animal is a more economic engine than any lifeless one we can construct. Even in the explanation of this there is involved a question of very great interest, still unsolved, though Joule and many other philosophers of the highest order have worked at it. Joule has given a suggestion of great value, viz. that the animal resembles an electromagnetic- rather than a heat-engine; but this throws us back again upon our difficulties as to the nature of electricity. Still, even supposing this question fully answered, there remains another—perhaps the highest which the human intellect is capable of directly attacking, for it is simply preposterous to suppose that we shall ever be able to understand scientifically the source of Consciousness and Volition, not to speak of loftier things—there remains the question of Life. Now it may be startling to some of you, especially if you have not particularly considered the matter, to hear it surmised that possibly we may, by the help of physical principles, especially that of the Dissipation of Energy, some time attain to a notion of what constitutes Life—mere Vitality I repeat, nothing higher. If you think for a moment of the vitality of a plant or a zoophyte, the remark perhaps will not appear so strange after all. But do not fancy that the Dissipation of Energy to which I refer is at all that of a watch or such-like piece of mere human mechanism, dissipating the low and common form of energy of a single coiled spring. It must be such that every little part of the living organism has its own store of energy constantly being dissipated, and as constantly replenished from external sources drawn upon by the whole arrangement in their harmonious working together. As an illustration of my meaning, though an extremely inadequate one, suppose Vaucanson's Duck to have been made up of excessively small parts, each microscopically constructed as perfectly as was the comparatively coarse whole, we should have had something barely distinguishable, save by want of instincts, from the living model. But let no one imagine that, should we ever penetrate this mystery, we shall thereby be enabled to produce, except from life, even the lowest form of life. Our President's splendid suggestion of Vortex-atoms, if it be correct, will enable us thoroughly to understand matter, and mathematically to investigate all its properties. Yet its very basis implies the *absolute necessity* of an intervention of Creative Power to form or to destroy one atom even of dead matter. The question really stands thus:—Is Life physical or no? For if it be in any sense, however slight or restricted, physical, it is to that extent a subject for the Natural Philosopher, and for him alone. It would be entirely out of place for me to discuss such a question as this now and here; I have introduced it merely that I may say a word or two about what has been so often and so persistently croaked against the British Association, viz. that it

tends to develope what are called Scientific Heresies. No doubt such charges are brought more usually against other Sections than against this; but Section A has not been held blameless. It seems to me that the proper answer to all such charges will be very simply and easily given, if we merely show that in our reasonings from observation and experiment we invariably confine our physical conclusions strictly to matter and energy (things which we can weigh and measure) in their multiform combinations. Excepting that which is obviously purely mathematical, whatever is certainly neither matter nor energy, nor dependent upon these, *is not a subject to be discussed here*, even by implication. All our reasonings in Physics *must*, so far as we know, be based upon the assumption, founded on experience, that in the universe, whatever be the epoch or the locality, under exactly similar circumstances exactly similar results will be obtained. If this be not granted there is an end of Physical Science, or, rather, there never could have been such a Science*. To use the word "Heresy" with reference to purely physical reasonings about Geological Time, or matters of that kind, is nowadays a piece of folly which even Galileo's judges, were they alive, would shrink from, as calculated to damage none but themselves and the cause which of old they, according to their lights, very naturally maintained.

There must always be wide limits of uncertainty (unless we choose to look upon Physics as a necessarily finite Science) concerning the exact boundary between the Attainable and the Unattainable. One herd of ignorant people, with the sole *prestige* of rapidly increasing numbers, and with the adhesion of a few fanatical deserters from the ranks of Science, refuse to admit that all the phenomena even of ordinary dead matter are strictly and exclusively in the domain of physical science. On the other hand, there is a numerous group, not in the slightest degree entitled to rank as Physicists (though in general they assume the proud title of Philosophers), who assert that not merely Life, but even Volition and Consciousness are mere physical manifestations. These opposite errors, into neither of which is it possible for a genuine scientific man to fall, so long at least as he retains his reason, are easily seen to be very closely allied. They are both to be attributed to that Credulity which is characteristic alike of Ignorance and of Incapacity. Unfortunately there is no cure; the case is hopeless, for great ignorance almost necessarily presumes incapacity, whether it show itself in the comparatively harmless folly of the Spiritualist or in the pernicious nonsense of the Materialist.

Alike condemned and contemned, we leave them to their proper fate—oblivion; but still we have to face the question, where to draw the line between that which is physical and that which is utterly beyond physics. And, again, our answer is—Experience alone can tell us; for experience is our only possible guide. If we attend earnestly and honestly to its teachings, we shall never go far astray. Man has been left to the resources of his intellect for the discovery not merely of physical laws, but of how far he is capable of comprehending them. And our answer to those who denounce our legitimate studies as heretical is simply this,—A revelation of any thing which we can discover for ourselves, by studying the ordinary course of nature, would be an absurdity.

A profound lesson may be learned from one of the earliest little papers of President, published while he was an undergraduate at Cambridge, where he shows that Fourier's magnificent treatment of the Conduction of Heat leads to formulæ for its distribution which are intelligible (and of course capable of being fully verified by experiment) for all time future, but which, except in particular cases, when extended to time past, remain intelligible for a finite period only, and *then*

* It might be possible, and, if so, perhaps interesting, to speculate on the results of secular changes in physical laws, or in particles of matter which are subject to them, but (so far as experience, which is our *only* guide, has taught us since the beginning of modern science) there seems no trace of such. Even if there were, as these changes must be of necessity extremely slow (because not yet even suspected), we may reasonably expect, from the analogy of the history of such a question as gravitation, especially in the discovery of Neptune, that our work, far from becoming impossible, will merely become considerably more difficult as well as more laborious, but, on that account, all the more creditable when successfully carried out.

indicate a state of things which could not have resulted under known laws from any conceivable previous distribution. So far as heat is concerned, modern investigations have shown that a previous distribution of the *matter* involved may, by its potential energy, be capable of producing such a state of things at the moment of its aggregation; but the example is now adduced not for its bearing on heat alone, but as a simple illustration of the fact that all portions of our Science, and especially that beautiful one the Dissipation of Energy, point unanimously to a beginning, to a state of things incapable of being derived by present laws from any conceivable previous arrangement.

I conclude by quoting some noble words used by Stokes in his Address at Exeter, words which should be stereotyped for every Meeting of this Association:— "When from the phenomena of life we pass on to those of mind, we enter a region "still more profoundly mysterious. . . . . . Science can be expected to do but little "to aid us here, since the instrument of research is itself the object of investigation. "It can but enlighten us as to the depth of our ignorance, and lead us to look to a "higher aid for that which most nearly concerns our wellbeing."

MATHEMATICS.

Exhibition and Description of a Model of a Conoidal Cubic Surface called the "Cylindroid," which is presented in the Theory of the Geometrical Freedom of a Rigid Body. By ROBERT STAWELL BALL, *A.M., Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.*

We become acquainted with the geometrical freedom which a rigid body enjoys by ascertaining the character of all the displacements which the nature of the restraints will permit the body to accept.

If a displacement be infinitely small, it is produced by screwing the body along a certain screw.

If a displacement have finite magnitude, it is produced by an infinite series of infinitely small screw displacements.

For the analysis of geometrical freedom, we shall only consider infinitely small screw displacements. This includes the initial stages of all displacements.

To analyze the geometrical restraints of a rigid body we proceed as follows:—

Take any line in space. Conceive this line to be the axis about which screws are successively formed of every pitch from $-\infty$ to $+\infty$. (The pitch of a screw is the distance its nut advances when turned through the angular unit.) We endeavour successively to displace the body about each of these screws, and record the particular screw or screws, if any, about which the restraints have permitted the body to receive a displacement. The same process is to be repeated for every other line in space. If it be found that the restraints have not permitted the body to receive any one of these displacements, then the body is rigidly fixed in space.

If, after all the screws have been tried, the body be found capable of displacement about one screw only, the body possesses the lowest degree of freedom.

If one screw (A) be discovered, and, the trials being continued, a second screw (B) be found, the remaining trials may be abridged by considering the information which the discovery of two screws affords. It is in connexion with the two screws that the cylindroid is presented.

The body may receive any displacement about one or both of the two screws A and B.

The composition of these displacements gives a resultant which could have been produced by displacement about a single screw.

The locus of this single screw is the conoidal cubic surface which has been called the "cylindroid" (at the suggestion of Professor Cayley).

The equation of the cylindroid is

$$z(x^2+y^2)-2axy=0.$$

Any line (s) upon this surface is considered to be a screw, of which the pitch is

$$c+a\cos 2\theta,$$

where c is any constant, and θ is the angle between s and the axis of x.

The fundamental property of the cylindroid is thus stated. If any three screws of the surface be taken, and if a body be displaced by being screwed along each of these screws through a small angle proportional to the sine of the angle between the remaining screws, the body after the last displacement will occupy the same position that it did before the first.

For the complete determination of the cylindroid and the pitch of all its screws, we must have the quantities a and c. These quantities, as well as the position of the cylindroid in space, are completely determined when two screws of the system are known.

In the model of the cylindroid which was exhibited, the parameter a is 2·6 inches. The wires which correspond in the model with the generating lines of the surface represent the axes of the screws. The distribution of pitch upon the generating lines is shown by colouring a length of $2{\cdot}6\times\sin 2\theta$ inches upon each wire. The distinction between positive and negative pitches is indicated by colouring the former red and the latter black.

It is remarkable that the addition of any constant to all the pitches attributed in the model to the screws does not affect the fundamental property of the cylindroid.

When a rigid body is found capable of being displaced about a pair of screws, it is necessarily capable of being displaced about every screw on the cylindroid determined by that pair.

The theorem of the cylindroid includes, as particular cases, the well-known rules for the composition of two displacements parallel to given lines, or of two small rotations about intersecting axes.

If the parameter a be zero, the cylindroid reduces to a plane, and the pitches of all the screws become equal. If the arbitrary constant which expresses the pitch be infinite, we have the theorem for displacements, and if the pitch be zero, we have the theorem for rotations.

As far as the composition of two displacements is concerned, the plane can only be regarded as a degraded form of the cylindroid from which the most essential features have disappeared.

On the Number of Covariants of a Binary Quantic. *By* Professor Cayley, *D.C.L., F.R.S.*

The author remarked that it had been shown by Prof. Gordan that the number of the covariants of a binary quantic of any order was finite, and, in particular, that the numbers for the quintic and the sextic were 23 and 26 respectively. But the demonstration is a very complicated one, and it can scarcely be doubted that a more simple demonstration will be found. The question in its most simple form is as follows: viz. instead of the covariants we substitute their leading coefficients, each of which is a "seminvariant" satisfying a certain partial differential equation; say, the quantic is $(a, b, c \ldots k \between x, y)^n$, then the differential equation is $(a\partial_b+2b\partial_c \ldots +nj\partial_k)u=0$, which *quà* equation with $n+1$ variables admits of n independent solutions: for instance, if $n=3$, the equation is $(a\partial_b+2b\partial_c+3c\partial_d)u=0$, and the solutions are a, $ac-b^2$, $a^2d-3abc+2b^3$; the general value of u is $u=$ any function whatever of the last-mentioned three functions. We have to find the rational non-integral functions of these functions which are rational and integral functions of the coefficients; such a function is

$$\frac{1}{a^2}\{(a^2d-3abc+2b^3)^2+4(ac-b^2)^3\},$$

$$=a^2d^2+4ac^3+4b^3d-3b^2c^2-6abcd,$$

and the original three solutions, together with the last-mentioned function a^2d^2+&c., constitute the complete system of the seminvariants of the cubic function; viz. every other seminvariant is a rational *and integral* function of these. And so in the general case the problem is to complete the series of the n solutions a, $ac-b^2$,

$a^2d-3abc+2b^3$, $a^3e-4a^2bd+6ab^2c-3b^4$, &c. by adding thereto the solutions which, being rational but non-integral functions of these, are rational and integral functions of the coefficients; and thus to arrive at a series of solutions such that every other solution is a rational and integral function of these.

On a Canonical Form of Spherical Harmonics. *By* W. K. CLIFFORD, *B.A.*

The canonical form in question is an expression of the general harmonic of order n as the sum of a certain number of sectorial harmonics, this number being, when n is even, $\frac{5n-10}{2}$, and when n is odd, $\frac{5n-9}{2}$.

Laplace's operator, $\frac{d^2}{dx^2}+\frac{d^2}{dy^2}+\frac{d^2}{dz^2}$, may be obtained from the tangential equation of the imaginary circle $\xi^2+\eta^2+\zeta^2=0$, by substituting $\frac{d}{dx}$, $\frac{d}{dy}$, $\frac{d}{dz}$ for ξ, η, ζ. If, therefore, a form $U\equiv(x, y, z)^n$ is reduced to zero by this operator, it follows from Prof. Sylvester's theory of contravariants that the curve $U=0$ is connected by certain invariant relations with the imaginary circle. I find that U can be expressed in the form

$$U\equiv A^n+B^n+C^n+\ldots.,$$

where $A=0$, $B=0$,.... are great circles touching the imaginary circle, the number of terms being as above. Now if $L=0$, $M=0$ be two such great circles meeting in a real point a, and if ϕ be a longitude and θ latitude referred to a as pole, it is easy to see that

$$L^n+M^n=l\sin^n\theta\sin n\phi+m\sin^n\theta\cos n\phi,$$

a sum of two sectorial harmonics, which is the proposed reduction.

When n is less than five, exceptions of interest occur. For $n=3$, if we take a, b, corresponding points on the hessian of the *nodal curve* $U=0$ (Thomson and Tait, Treatise on Natural Philosophy, § 780), and if we call ϕ_1, ϕ_2 the longitudes, θ_1, θ_2 the latitudes referred to these poles, we have

$$\begin{aligned}U\equiv l\sin^3\theta_1\sin 3\phi_1+m\sin^3\theta_1\cos 3\phi_1\\ +n\sin^3\theta_2\sin 3\phi_2+s\sin^3\theta_2\cos 3\phi_2.\end{aligned}$$

For $n=4$, the nodal curve is of the species first noticed by Clebsch, of which many most beautiful properties have been pointed out by Dr. Lüroth. The form U is expressible as the sum of *five* fourth powers; so that if we take a, b real points of intersection of two pairs of them, c a real point on the fifth, calling ϕ_1, ϕ_2, ϕ_3, $\theta_1, \theta_2, \theta_3$ longitudes and latitudes referred to them, we have

$$\begin{aligned}U\equiv l\sin^4\theta_1\sin 4\phi_1+m\sin^4\theta_1\cos 4\phi_1\\ +p\sin^4\theta_2\sin 4\phi_2+q\sin^4\theta_2\cos 4\phi_2\\ +r\sin^4\theta_3\,\epsilon^{41\,\phi_3}.\end{aligned}$$

On certain Definite Integrals. *By* J. W. L. GLAISHER, *B.A.*, *F.R.A.S.*

The integrals $\int_0^\infty \sin(x^n)dx$, $\int_0^\infty \cos(x^n)dx$ have been evaluated in several different ways, and the investigations all present points of interest. The integrals have usually been written in the forms $\int_0^\infty x^{p-1}\sin x dx$, $\int_0^\infty x^{p-1}\cos x\, dx$, deducible by an obvious transformation; and so universally have the latter forms been adopted, that the former are not to be found in Prof. De Haan's Tables.

The most natural way of obtaining $\int_0^\infty \sin x^n dx$ and $\int_0^\infty \cos x^n dx$ is by writing $p=i(=\sqrt{-1})$ in the well-known form of the Gamma Function,

$$\int_0^\infty e^{-px^n}dx=\frac{1}{p^{\frac{1}{n}}}\Gamma\left(1+\frac{1}{n}\right);$$

we thus obtain

$$\int_0^\infty \cos x^n dx - i\int_0^\infty \sin x^n dx = \cos\frac{1}{n}\left(2k\pi+\frac{\pi}{2}\right) - i\sin\frac{1}{n}\left(2k\pi+\frac{\pi}{2}\right);$$

and we can equate real and imaginary terms. A curious difficulty, however, here presents itself, viz. to decide what value k (which must be integral) has. In a similar case De Morgan determined the proper value of k in the following manner:—Put $p=\cos\theta\pm i\sin\theta$, then

$$\int_0^\infty e^{-x^n\cos\theta}\{\cos(x^n\sin\theta)\pm i\sin(x^n\sin\theta)\}dx$$

$$=\left\{\cos\frac{1}{n}(2k\pi+\theta)\pm i\sin\frac{1}{n}(2k\pi+\theta)\right\}\Gamma\left(1+\frac{1}{n}\right);$$

whence

$$\int_0^\infty e^{-x^n\cos\theta}\cos(x^n\sin\theta)dx=\cos\frac{1}{n}(2k\pi+\theta)\Gamma\left(1+\frac{1}{n}\right),$$

$$\int_0^\infty e^{-x^n\cos\theta}\sin(x^n\sin\theta)dx=\sin\frac{1}{n}(2k\pi+\theta)\Gamma\left(1+\frac{1}{n}\right).$$

Now if $\theta=0$, the last integral vanishes; so that we must have $k=0$, and therefore

$$\int_0^\infty \cos x^n dx=\cos\frac{\pi}{2n}\Gamma\left(1+\frac{1}{n}\right),\quad \int_0^\infty \sin x^n dx=\sin\frac{\pi}{2n}\Gamma\left(1+\frac{1}{n}\right).$$

The above investigation is, however, chiefly valuable as *suggestive* of the result; it contains no indication of the limits between which n must lie that the last written equations may be true and the integrals not infinite. The integrals have also been obtained by differentiating $\int_0^\infty e^{-ax}\sin x dx$ with regard to a and putting $a=0$ afterwards; but the results obtained are of the form $\int_0^\infty x^n\sin x dx$ (n integral), and must therefore be infinite *. The following investigation of the values of the integrals seems of interest, as it is rigorous and discriminates between the finite and infinite values. Integrate $\int_0^\infty\int_0^\infty e^{-x^n y}\sin y\, dx\, dy$ with regard to x first, and we find it

$$=\Gamma\left(1+\frac{1}{n}\right)\int_0^\infty \frac{\sin y}{y^{\frac{1}{n}}}dy;$$

integrating with regard to x first, we find it

$$=\int_0^\infty \frac{dx}{1+x^{2n}}=\frac{\pi}{2n}\operatorname{cosec}\frac{\pi}{2n}\quad (2n>1),$$

$$=\infty\quad (2n<1),$$

whence

$$\int_0^\infty y^{-\frac{1}{n}}\sin y dy\,.\,\Gamma\left(1+\frac{1}{n}\right)=\frac{\pi}{2n}\operatorname{cosec}\frac{\pi}{2n};$$

* This method is also given in De Morgan's 'Differential and Integral Calculus,' pp. 630, 576. Some analysts (Oettinger, Bidone, &c.) have not seen any objection to $\int_0^\infty x^n\sin x dx$ being finite for all values of n; but unless we are prepared to write with De Morgan ("Theory of Probabilities," Encyc. Met. p. 436) $\int_0^\infty e^{px}dx=-\frac{1}{p}$, because $\int_0^\infty e^{-px}dx=\frac{1}{p}$, it is difficult to see how this can be admitted.

by taking $\frac{1}{m}=1-\frac{1}{n}$ (in which $2n>1$, so that m may have any value except such as lie between 1 and -1), and using the relation $\Gamma(\alpha)\Gamma(1-\alpha)=\pi \operatorname{cosec} \alpha\pi$, we obtain

$$\int_0^\infty \sin x^m dx=\Gamma\left(1+\frac{1}{m}\right)\sin\frac{\pi}{2m}.$$

Similarly, by integrating $\int_0^\infty \int_0^\infty e^{-x^n y} \cos y \, dx \, dy$, we find

$$\int_0^\infty \cos x^m dx=\Gamma\left(1+\frac{1}{m}\right)\cos\frac{\pi}{2m}$$

(m between 1 and ∞).

The author had calculated a Table of the values of $\int_0^\infty \sin x^n dx$, $\int_0^\infty \cos x^n dx$ for different values of x; and the curves $y=\int_0^\infty \sin a^x da$, $y=\int_0^\infty \cos a^x da$, as obtained from them, were drawn and exhibited to the Section, the discontinuities in each being remarked. [The Tables and curves will be found in the 'Messenger of Mathematics,' 1871.]

On Lambert's Proof of the Irrationality of π, *and on the Irrationality of certain other Quantities.* By J. W. L. Glaisher, *B.A.*, *F.R.A.S.*

The arithmetical quadrature of the circle, that is to say, the expression of the ratio of the circumference to the diameter in the form of a vulgar fraction with both numerator and denominator finite quantities, was shown to be impossible by Lambert in the 'Berlin Memoirs' for 1761; and the proof has since been given in an abridged and modified form by Legendre in the Notes to his 'Éléments de Géométrie.' Although Legendre's method is quite as rigorous as that on which it is founded, still, on the whole, the demonstration of Lambert seems to afford a more striking and convincing proof of the truth of the proposition; his investigation, however, is given in such detail, and so many properties of continued fractions, now well known, are proved, that it is not very easy to follow his reasoning, which extends over more than thirty pages. The object of the present paper is to exhibit Lambert's demonstration of this important theorem concisely, and in a form free from unnecessary details, and to apply his method to deduce some results with regard to the irrationality of certain circular and other functions.

The theorem which Lambert proves, and from which he deduces the irrationality of π, is that *the tangent of a rational arc* (i. e. *an arc commensurable with the radius*) *must be irrational*; and this he demonstrates by means of an expression for the tangent as a continued fraction, viz.

$$\tan\frac{x}{y}=\frac{x}{y-}\,\frac{x^2}{3y-}\,\frac{x^2}{5y-}\,\frac{x^2}{7y-\&c.}, \quad \text{(i)}$$

adopting an established notation for continued fractions in which that which follows each minus-sign is written as a factor, to save room.

Consider a continued fraction

$$\frac{\beta_1}{\alpha_1+}\,\frac{\beta_2}{\alpha_2+}\,\frac{\beta_3}{\alpha_3+\&c.}, \quad \text{(ii)}$$

and let $\frac{p_n}{q_n}$ be the nth convergent to it; then we know that

$$p_n=\alpha_n p_{n-1}+\beta_n p_{n-2},$$

$$q_n=\alpha_n q_{n-1}+\beta_n q_{n-2},$$

and

$$\frac{p_n}{q_n}-\frac{p_{n-1}}{q_{n-1}}=(-)^{n-1}\frac{\beta_1\beta_2\ldots\beta_n}{q_{n-1}q_n}* \quad \text{(iii)}$$

* These results can easily be proved by induction.

Suppose also that the continued fraction (i) is equal to $\frac{P}{Q}$, and let $R_1, R_2 \dots R_n \dots$ be such that

$$\begin{aligned} R_1 &= \alpha_1 P - \beta_1 Q, \\ R_2 &= \alpha_2 R_1 + \beta_2 P, \\ R_3 &= \alpha_3 R_2 + \beta_3 R_1, \\ &\cdots\cdots \\ R_n &= \alpha_n R_{n-1} + \beta_n R_{n-2}, \\ &\cdots\cdots \end{aligned}$$

then $R_n = q_n P - p_n Q$, as can be shown by induction; so that

$$\frac{P}{Q} - \frac{p_n}{q_n} = \frac{R_n}{Q q_n}. \qquad \text{(iv)}$$

Now

$$\frac{P}{Q} = \frac{p_n}{q_n} + \left(\frac{p_{n+1}}{q_{n+1}} - \frac{p_n}{q_n}\right) + \left(\frac{p_{n+2}}{q_{n+2}} - \frac{p_{n+1}}{q_{n+1}}\right) + \dots;$$

therefore

$$\frac{P}{Q} - \frac{p_n}{q_n} = (-)^n \frac{\beta_1 \dots \beta_{n+1}}{q_n q_{n+1}} + (-)^{n+1} \frac{\beta_1 \dots \beta_{n+2}}{q_{n+1} q_{n+2}} + \dots$$

from (iii). By equating this value of $\frac{P}{Q} - \frac{p_n}{q_n}$ to that in (iv), we obtain

$$(-)^{n+1} R_n = Q \frac{\beta_1 \dots \beta_{n+1}}{q_{n+1}} - Q q_n \frac{\beta_1 \dots \beta_{n+2}}{q_{n+1} q_{n+2}} + \dots. \qquad \text{(v)}$$

If P and Q be integers and $\alpha_1 \dots \alpha_n \dots \beta_1 \dots \beta_n \dots$ be also all integers, then from the equations by which $R_1 \dots R_n \dots$ are determined, we see that they also are integers.

Now in the case of the continued fraction for $\tan \frac{x}{y}$,

$$\begin{aligned} \alpha_n &= (2n-1)y, \\ \beta_n &= -x^2, \\ q_n &= (2n-1)y q_{n-1} - x^2 q_{n-2}; \end{aligned}$$

and we notice that if x and y be integers, then $\alpha_1 \dots \alpha_n \dots \beta_1 \dots \beta_n \dots$ are so too, and consequently (if P and Q are integers) $R_1 \dots R_n \dots$ are integers.

The factor by which $\frac{\beta_1 \dots \beta_r}{q_r}$ is multiplied to obtain $\frac{\beta_1 \dots \beta_{r+1}}{q_{r+1}}$ is

$$\begin{aligned} \frac{\beta_{r+1} q_r}{q_{r+1}} &= \pm \frac{x^2 q_r}{(2r+1) y q_r - x^2 q_{r-1}} \\ &= \pm \frac{x^2}{(2r+1) y - x^2 \frac{q_{r-1}}{q_r}}, \end{aligned}$$

which can be made as small as we please by increasing r.

We can therefore from (v), Q being finite, make R_n as small as we please by taking n sufficiently large; but if P and Q be both integers, R_n must remain an integer whatever value n may have; thus if $\frac{x}{y}$ be rational, $\frac{P}{Q}\left(= \tan \frac{x}{y}\right)$ must be irrational; but $\tan \frac{\pi}{4} = 1$, so that $\frac{\pi}{4}$ cannot be rational.

The above is in substance Lambert's demonstration; alterations have been made in points of detail &c., and the notation has been changed.

It may be noticed that the proof does not (as of course it should not) hold good if P and Q be infinite integers; for we cannot make R_n as small as we please in (v) if Q be infinite.

Legendre proves a theorem which is easily seen to follow directly from Lambert's mode of investigation, viz. that if in the continued fraction

$$\frac{\beta_1}{\alpha_1+}\,\frac{\beta_2}{\alpha_2+}\,\frac{\beta_3}{\alpha_3+\&c.}\text{ (extended to infinity),}$$

$\frac{\beta_1}{\alpha_1}, \frac{\beta_2}{\alpha_2}\ldots$, regarded as fractions ($\alpha_1 \ldots \beta_1 \ldots$, all integers), be all less than unity, then, whether $\beta_1, \beta_2 \ldots$ be all positive or all negative, or some positive and some negative, the value of the continued fraction is irrational. He also remarks that π^2 must be irrational; for if it $=\frac{m}{n}$, we should have, from (i), since $\tan \pi = 0$,

$$3 = \frac{m}{5n-}\,\frac{m}{7-}\,\frac{m}{9n-\&c.};$$

and as after some value of r the fractions $\frac{m}{(2r+1)n}, \frac{m}{2r+3}$, &c. must be less than unity, 3 must be irrational if m and n are integers, whence π^2 is irrational.

The expression of $\tan v$ in the form of a continued fraction Lambert obtained by treating $\sin v$ or $v-\frac{v^3}{1.2.3}+\ldots$ and $\cos v$ or $1-\frac{v^2}{1.2}+\ldots$ in a manner analogous to that in which the greatest common measure of two numbers is found in arithmetic; and Legendre deduced it from a more general theorem he had proved with regard to the conversion of the ratio of two series into a continued fraction. It may be obtained very simply by forming the differential equation corresponding to $y = \mathrm{A}\cos(\sqrt{2x}+\mathrm{B})$, viz.

$$y+y'+2xy''=0,$$

whence $y^{(i)}+(2i+1)y^{(i+1)}+2xy^{(i+2)}=0$ by application of Leibnitz's theorem.

From this we have

$$\frac{y'}{y} = \frac{-1}{1+2x\frac{y''}{y'}},$$

$$\frac{y''}{y'} = \frac{-1}{3+2x\frac{y'''}{y''}},$$

&c.;

therefore

$$\frac{y'}{y} = -\frac{1}{\sqrt{(2x)}}\tan\{\sqrt{(2x)}+\mathrm{B}\} = \frac{-1}{1-}\,\frac{2x}{3-}\,\frac{2x}{5-\&c.};$$

whence, after determining B by putting $x=0$ and writing $\sqrt{(2x)}=v$,

$$\tan v = \frac{v}{1-}\,\frac{v^2}{3-}\,\frac{v^2}{5-\&c.}.$$

That Lambert's proof is perfectly rigorous and places the fact of the irrationality of π beyond all doubt, is evident to every one who examines it carefully; and considering the small attention that had been paid to continued fractions previously to the time at which it was written, it cannot but be regarded as a very admirable work.

From the continued fraction

$$\frac{e^n+1}{2} = \frac{1}{1-}\,\frac{1}{2n^{-1}+}\,\frac{1}{6n^{-1}+}\,\frac{1}{10n^{-1}+\&c.},$$

Lambert showed, in the same memoir, that e^n is irrational, so that the Napierian logarithm of every rational number is irrational.

We can obtain a little more information about the irrationality of $e^{\frac{1}{x}}$, for we have

$$\frac{e^{\frac{1}{x}}-1}{2} = \frac{1}{2x-1+}\,\frac{1}{6x+}\,\frac{1}{10x+\&c.}.$$

Now any continued fraction in which all the numerators are unity and all the denominators are positive integers must circulate if it be the development of an expression of the form $A+B\sqrt{C}$; so that we see that $e^{\frac{1}{x}}$, when x is integral, cannot be of this form.

Taking the expression for the tangent in the form

$$\cot\frac{1}{x}=\frac{1}{x-1+}\,\frac{1}{1+}\,\frac{1}{3x-2+}\,\frac{1}{1+}\,\frac{1}{5x-2+\&c.}\,*$$

we see that when x is an integer, $\cot\frac{1}{x}$ is irrational, but cannot be of the form $A+B\sqrt{C}$.

Also, since $\operatorname{cosec}\frac{1}{x}=\sqrt{\left(1+\cot^2\frac{1}{x}\right)}$, and $\sec\frac{1}{x}=\dfrac{\sqrt{\left(1+\cot^2\frac{1}{x}\right)}}{\cot\frac{1}{x}}$, $\sin\frac{1}{x}$ and $\cos\frac{1}{x}$ cannot either of them be rational unless $\cot\frac{1}{x}$ is of the form $B\sqrt{C}$, which not being the case, $\sin\frac{1}{x}$ and $\cos\frac{1}{x}$ are irrational, and cannot be of the form $B\sqrt{C}$.

Since $\cos\frac{2}{x}=2\cos^2\frac{1}{x}-1$, $\cos\frac{2}{x}$ cannot be rational unless $\cos\frac{1}{x}=B\sqrt{C}$, which would require that $\cot\frac{1}{x}=\sqrt{\left(\frac{B^2C}{1-B^2C}\right)}$, a form which we have shown it cannot have; so that $\cos\frac{2}{x}$ is irrational. Similar results hold good for the hyperbolic sine and cosine; that is to say, $\frac{1}{2}(e^{\frac{1}{x}}+e^{-\frac{1}{x}})$, $\frac{1}{2}(e^{\frac{1}{x}}-e^{-\frac{1}{x}})$, and $\frac{1}{2}(e^{\frac{2}{x}}+e^{-\frac{2}{x}})$ are irrational.

It may be remarked that it is easy to show that $\sin\frac{1}{x}$ is incommensurable from the series; for if $\sin\frac{1}{x}=\frac{p}{q}$, then ($q$ even, as of course we may take it)

$$\frac{p}{q}=\frac{1}{x}-\frac{1}{1.2.3x^3}+\ldots(-)^{\frac{q}{2}-1}\frac{1}{1.2..(q-1)x^{q-1}}+(-)^{\frac{q}{2}}\frac{1}{1.2..(q+1)x^{q+1}}+\ldots;$$

whence, multiplying both sides by $(1.2\ldots q)x^{q-1}$,

$$p\{1.2\ldots(q-1)\}x^{q-1}=\text{integer}+(-)^{\frac{q}{2}}\left(\frac{1}{(q+1)x^2}-\frac{1}{(q+1)(q+2)(q+3)x^4}\ldots\right),$$

and the series on the right-hand side must be intermediate in value to $\frac{1}{(q+1)x^2}$ and $\frac{1}{(q+1)(q+2)(q+3)x^4}$, and is therefore fractional; thus we have

$$\text{integer}=\text{integer}+\text{fraction}$$

if $\sin\frac{1}{x}$ is commensurable. An exactly similar method proves the irrationality of $\cos\frac{1}{x}$, $\frac{1}{2}(e^{\frac{1}{x}}-e^{-\frac{1}{x}})$, &c., but gives no result when applied to $\cos\frac{2}{x}$ or $\frac{1}{2}(e^{\frac{2}{x}}+e^{-\frac{2}{x}})$. It is probably true that both the sine and cosine of every rational arc are irrational, though no proof of this has, I believe, been given; and there is, as Legendre has remarked, very little doubt that π is not only not the square root of a rational quantity, but also not even the root of any algebraical equation with rational coefficients, although the demonstration of this seems difficult. Similar remarks may be made with respect to e.

* This expression can be deduced from (i) by transforming the terms of the latter thus:

$$A-\frac{1}{B}=A-1+\cfrac{1}{1+\cfrac{1}{B-1}}.$$

An instance of the application of Lambert's principle is afforded by a theorem of Eisenstein (Crelle's Journal, t. xxix. p. 96), viz.

$$1+\frac{1}{z}+\frac{1}{z^3}+\frac{1}{z^6}+\ldots=\frac{1}{1-}\,\frac{1}{z-}\,\frac{1-z}{z-}\,\frac{1}{z^2-}\,\frac{1-z^2}{z^2-\&c.},$$

whence the series is always irrational when z is an integer greater than unity.

The series $\frac{1}{a_1}-\frac{1}{a_2}+\frac{1}{a_3}-\frac{1}{a_4}+\ldots$ can be converted into the continued fraction $\frac{1}{a_1+}\,\frac{a_1^2}{a_2-a_1+}\,\frac{a_2^2}{a_3-a_2+}\,\frac{a_3^2}{a_4-a_3+\&c.}$; so that if after any finite value of r, $a_r^2+a_r$ is always less than a_{r+1}, the sum of the series is irrational. Also from the equality

$$\frac{1}{b_1}-\frac{1}{b_1b_2}+\frac{1}{b_1b_2b_3}-\ldots=\frac{1}{b_1+}\,\frac{b_1}{b_2-1+}\,\frac{b_2}{b_3-1+\&c.}$$

we see that if after any finite integral b_r+1 is always less than b_{r+1}, the sum of the series is irrational.

On the Calculation of e (*the base of the Napierian Logarithms*) *from a Continued Fraction.* *By* J. W. L. GLAISHER, *B.A., F.R.A.S.*

The series by which e is defined, viz.

$$1+1+\frac{1}{1.2}+\frac{1}{1.2.3}+\ldots, \quad \ldots \ldots \quad (1)$$

is of a very convergent class, so that it would be reasonable to expect that no better formula could be found for its calculation. Taking the series in the form

$$1-\frac{1}{e}=1-\frac{1}{1.2}+\frac{1}{1.2.3}-\ldots,$$

and throwing it into the form of a continued fraction by the usual method, we have

$$1-\frac{1}{e}=\frac{1}{1+}\,\frac{1}{1+}\,\frac{2}{2+}\,\frac{3}{3+\ldots};$$

and from the manner in which the continued fraction is deduced from the series, it is clear that the nth convergent of the former corresponds to n terms of the latter. There is, however, a far more convergent fraction from which e can be computed, viz.

$$\frac{e-1}{2}=\frac{1}{1+}\,\frac{1}{6+}\,\frac{1}{10+\ldots}\,\frac{1}{4n+2+\ldots}, \quad \ldots \ldots \quad (2)$$

a formula given by Lambert (Berlin Memoirs, 1761), who obtained it by performing on $\frac{e^x-e^{-x}}{e^x+e^{-x}}$ an operation similar to that affording the greatest common measure of its numerator and denominator. Another investigation is given by Legendre in the Notes to his 'Géométrie;' and this is reproduced in the Notes to the French translation of Euler's 'Introductio ad Analysin.' It can also be very easily obtained from the differential equation

$$y-\frac{dy}{dx}-2x\frac{d^2y}{dx^2}=0,$$

corresponding to $y=e^{\sqrt{(2x)}}$, as the fraction for $\tan v$ was found in the previous paper.

The continued fraction (2) is much more convergent than the series, and I was tempted to calculate the value of e from it for two reasons:—(1) In order to practically test the advantages of a continued fraction and a series as a formula for calculation with respect to the arrangement and performance of the operations; and (2) to decide between two different values of e which have been given—the one by Callet in all the editions of his 'Logarithmes Portatives,' and the other by Mr. Shanks in his 'Rectification of the Circle,' and Proc. Roy. Soc. vol. vi. p. 397. The several convergents to the value of e also seemed to be of value.

Taking (2) in the form

$$e=1+\frac{2}{1+}\,\frac{1}{6+}\,\frac{1}{10+\ldots}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and writing the convergents $\frac{p_1}{q_1}, \frac{p_2}{q_2}, \ldots$, so that $p_1=1$, $p_2=3\ldots$, $q_1=1$, $q_2=1\ldots$, the convergents were calculated as far as $\frac{p_{39}}{q_{39}}$ (which corresponds to the quotient 150). The following Table contains the values of the convergents as far as $\frac{p_{20}}{q_{20}}$.

n.	p_n.	q_n.
3	19	7
4	193	71
5	2 721	1 001
6	49 171	18 089
7	1 084 483	398 959
8	28 245 729	10 391 023
9	848 456 353	312 129 649
10	28 875 761 731	10 622 799 089
11	1 098 127 402 131	403 978 495 031
12	46 150 226 651 233	16 977 719 590 391
13	2 124 008 553 358 849	781 379 079 653 017
14	106 246 577 894 593 683	39 085 931 702 241 241
15	5 739 439 214 861 417 731	2 111 421 691 000 680 031
16	332 993 721 039 856 822 081	122 501 544 009 741 683 039
17	20 651 350 143 685 984 386 753	7 597 207 150 294 985 028 449
18	1 363 322 103 204 314 826 347 779	501 538 173 463 478 753 560 673
19	95 453 198 574 445 723 828 731 283	35 115 269 349 593 807 734 275 559
20	7 064 900 016 612 187 878 152 462 721	2 599 031 470 043 405 251 089 952 039

p_{39}=5 933 736 817 524 490 649 943 748 885 310 086 922 977 536 976 487 014 058 103 672 162 883,

q_{39}=2 182 899 784 489 322 239 844 266 493 459 455 750 162 013 065 305 797 591 300 833 210 159.

Since
$$e=\frac{p_n}{q_n}+\left(\frac{p_{n+1}}{q_{n+1}}-\frac{p_n}{q_n}\right)+\left(\frac{p_{n+2}}{q_{n+2}}-\frac{p_{n+1}}{q_{n+1}}\right)+\ldots$$
$$=\frac{p_n}{q_n}+(-)^{n+1}\left(\frac{2}{q_nq_{n+1}}-\frac{2}{q_{n+1}q_{n+2}}+\ldots\right),$$

we see that e differs from $\frac{p_n}{q_n}$ by less than $\frac{2}{q_nq_{n+1}}$; if $n=39$, $\frac{2}{q_nq_{n+1}}$=(134 ciphers) 272...; so that 135 figures of the result obtained by dividing p_{39} by q_{39} are correct. On performing the division to 137 places and applying the correction for $\frac{2}{q_nq_{n+1}}$, the value of e was obtained to 137 decimal places, viz.

e=2·71828 18284 59045 23536 02874 71352 66249
77572 47093 69995 95749 66967 62772 40766
30353 54759 45713 82178 52516 64274 27466
39193 20030 59921 81741 35966 29043 57...,

which agrees with Mr. Shanks's calculation obtained from the series

$$e=1+1+\frac{1}{1.2}+\frac{1}{1.2.3}+\ldots$$

to the last figure; there is therefore no doubt of the accuracy of the result to this extent.

The value given by Callet, in the introduction to his 'Tables Portatives,' starting with the ninth group of five, is

...46928 08355 51550 58417 2...;

and these figures should be

...47093 69995 95749 66967 6....

The thirty-ninth convergent to the continued fraction (3) gives a result as accurate as that found by summing the first ninety terms of the series (1); but there would be no great disparity between the absolute number of figures formed in the two calculations. The computation of the convergents was, however, far preferable in point of arrangement and convenience to the calculation of the successive terms of a series; for not only were the divisions in the latter replaced by multiplications, which are far more compact, but the work in the former case ran straight forward and required no copying of results. There is also another very great advantage in the continued fraction: the great difficulty of performing a piece of work to a considerable number of decimal places is the inconvenience caused by the length of the numbers; and in the above calculation we get roughly $2n$ figures of the result without ever having to use a number more than n figures long in the work: thus p_{39} and q_{39} contain each 67 figures, and by dividing them we obtain 138 figures of the result; this advantage is due to the fact that all the numerators in (3), except the first, are equal to unity. It may be remarked that the final division was the most laborious part of the work; the calculation of p_{39} and q_{39} required barely 13,000 figures, the division about 18,000.

We can compare the number of decimal places afforded by (3) and (1) when n *is large* as follows:—The number of places $\frac{p_n}{q_n}$ yields* is equal to the greatest integer contained in

$$\log\frac{q_n q_{n+1}}{2}=\log\left[\tfrac{1}{2}\{1.6\ldots(4n-6)\}\{1.6\ldots(4n-2)\}\right]$$

$$=\log\left[\frac{2^{2n-4}}{4n}\{1.3\ldots(2n-1)\}^2\right]=\log\left[\frac{2^{2n-6}}{n}.2^{-2n}\left\{\frac{\Gamma(2n+1)}{\Gamma(n+1)}\right\}^2\right]$$

$$=\log\left[\frac{1}{64n}\left\{\frac{n^{2n+\frac{1}{2}}2^{2n+\frac{1}{2}}}{n^{n+\frac{1}{2}}e^n}\right\}^2\right],$$

(after substituting $\sqrt{2\pi n}\,n^n e^{-n}$ for $\Gamma(n+1)$)

$$=\log\left\{\frac{2^{4n-5}}{n}.\left(\frac{n}{e}\right)^{2n}\right\}=2n\log\frac{n}{e}+(4n-5)\log 2-\log n;$$

and the number of places obtained from n terms of (1) is equal to the greatest integer in

$$\log\Gamma(n)=n\log\frac{n}{e}+\tfrac{1}{2}\log 2\pi-\tfrac{1}{2}\log n;$$

so that the nth convergent to the continued fraction gives more than twice as many decimal places as n terms of the series.

On certain Families of Surfaces. By C. W. MERRIFIELD, *F.R.S.*

The author had already shown that conical and cylindrical surfaces not only satisfy the general equation of developable surfaces in differentials of the second order,

$$rt=s^2,$$

but also that on passing to the differential equation of the third order, there are two equal roots in the case of conical surfaces and three equal roots in the case of cylindrical surfaces.

* See Proc. Roy. Soc. vol. xix. p. 514.

An examination of the surfaces described by the motion of a plane parabola of any order with its diameters parallel to a fixed right line showed that the condition of a pair of equal roots in the equation of the third order,

$$\left(\frac{d}{dx}+\lambda\frac{d}{dy}\right)^3 z=0,$$

considered as an equation in λ, was satisfied by all surfaces traced out by a plane parabola moving parallel to a fixed line and enveloping any curve in space whatever. As singular cases, he noticed the spindle made by causing a parabola (whether fixed or of variable size) to rotate round any diameter, the ruled surface with a director plane, and developable surfaces.

He also showed that when three of the roots were equal, the surface necessarily reduced to a plane or a cylinder.

These results are, however, restricted by the method of generating the surface. In fact, for the case of three equal roots, when the partial differentials of the third order are in continued proportion, Mr. Cayley has shown that the resulting equations can be integrated and that the integration gives a more general result.

Note by Mr. Cayley.

The general integral of the equations

$$\frac{\alpha}{\beta}=\frac{\beta}{\gamma}=\frac{\gamma}{\delta}$$

can be found, viz. $\frac{\alpha}{\beta}=\frac{\beta}{\gamma}$ gives $r=$ funct. s, and $\frac{\beta}{\gamma}=\frac{\gamma}{\delta}$ gives $s=$ funct. t. But $r=$ funct. s is integrated as the equation of a developable surface (p instead of z), viz. we have, say,

$$p=ax+hy+g \ (a \text{ and } g \text{ functions of } h) \text{ and}$$

$$0=a'x+y+g', \quad \left(a'=\frac{da}{dh},\ g'=\frac{dg}{dh}\right).$$

Similarly $s=$ funct. t gives

$$q=hx+by+f,$$

$$0=x+b'y+f', \quad \left(b'=\frac{db}{dh},\ f'=\frac{df}{dh}\right).$$

Observe that the constants have been taken so that $\frac{dp}{dy}=h$, $\frac{dq}{dx}=h$; but in order that h may in the two pairs of equations mean the same function of x, y, we must have $a'=\frac{1}{b'}=\frac{g'}{f'}$, that is

$$b=\int\frac{dh}{a'},\quad f=\int\frac{g'dh}{a'}:$$

or writing $a=\phi h$, $g=\chi h$, we have

$$p=x\phi h+yh+\chi h,\quad q=hx+y\int\frac{dh}{\phi' h}+\int\frac{\chi hd}{\phi h},$$

where

$$x\phi' h+y+\chi' h=0.$$

The last equation gives h as a function of x, y; and the values of p, q are then such that $dz=pdx+qdy$ is a complete differential, so that we obtain z by the integration of this equation. A simple example is

$$p=\tfrac{1}{2}h^2x-hy,\quad q=-hx+y\log h,\quad hx-y=0;$$

that is

$$p=-\frac{1}{2}\frac{y^2}{x},\quad q=-y+y\log\frac{y}{x};$$

whence

$$z=\frac{1}{2}y^2\log\frac{y}{x}-\frac{3}{4}y^2.$$

We have

$$r=\frac{1}{2}\frac{y^2}{x^2}, \quad s=-\frac{y}{x}, \quad t=\log\frac{y}{x},$$

$$\alpha=-\frac{y^2}{x^3}, \quad \beta=\frac{y}{x^2}, \quad \gamma=-\frac{1}{x}, \quad \delta=\frac{1}{y};$$

and $\frac{\alpha}{\beta}=\frac{\beta}{\gamma}=\frac{\gamma}{\delta}\left(=-\frac{y}{x}\right)$, as it should be.

On Doubly Diametral Quartan Curves.

By F. W. Newman, *Emeritus Professor of University College, London.*

This paper aimed to detail the *form* of the curves, and point out the simplest *modes* of investigating their peculiarities. It distributed the general equation into three groups of five, five, and four families, and was accompanied by seventy-six diagrams.

If we call

$$Ax^4+2Dx^2y^2+By^4+2Ex^2+2Fy^2+C=0$$

the general equation, the first group of five families is when A or B or both vanish, the second group when D or F or both vanish, and these together nearly include all the forms. For in the third group, from which either *no* term of the original equation vanishes, or only C, three of the families are at once reducible to the second group by putting either $y^2+f^2=y'^2$, else $x^2+e^2=x'^2$; then the proposed curve of (xy) is visibly at most a mere variety of the preceding, being either of the same species with, or of a lower species than, that of (xy') or of $(x'y)$. In the case of $B=\beta^2$, $D=\delta^2$, $F=-f'^2$, this reduction is impossible; but then by operating on x instead of y, it becomes possible unless also $A=\alpha^2$, $E=-e'^2$; that is, the method fails only when A, B, D are of one sign, and E, F of the opposite. The analysis, thus limited, readily yields the same result, that the forms have nothing new.

A cross division of the species is into Limited and Unlimited loci. All are Centric, the origin being the Centre. Finite forms are Monads, Duads, and Tetrads.

Monads are:—1. A symmetrical oval (say, a *Shield*), as from

$$x^2y^2+a^2y^2+b^2x^2=m^4.$$

2. An Oval with undulating sides (*Viol* or Dumb-bell), as $a^2y^2=(m^2-x^2)(x^2+n^2)$, $m^2>n^2$. 3. A Lemniscate or *Double Loop*, as $a^2y^2=(m^2-x^2)x^2$. 4. A *Scutcheon*, with four sides undulating, as $\beta^2y^2=f^2\pm\sqrt{(m^2-x^2)(x^2+n^2)}$, when $m^2>n^2$, and $f^2<mn$. 5. *Ovals in Contact*, as $\beta^4y^4=(m^2-x^2)x^2$. 6. *Pointed Hearts*, crossing obliquely at the centre, as

$$\beta^2y^2=mn+\delta^2x^2\pm\sqrt{\{(m^2-x^2)(x^2+n^2)\}},$$

when $m^2-n^2>2mn$, and $\delta^2>\frac{m^2-n^2}{2mn}$. 7. *Hearts in Contact*; the same equation as before, only with $\delta^2=\frac{m^2-n^2}{2mn}$. 8. *Intersecting Hearts*, as

$$\beta^2y^2=\tfrac{1}{2}(m^2+n^2)\pm\sqrt{\{(m^2-x^2)(x^2+n^2)\}},$$

when $m^2>n^2$. 9. *Intersecting Ovals*: the same equation as in 8, only with $m^2\overline{\overline{<}}n^2$. All curves are here deemed *Monads* which can be drawn without taking the pencil off the paper.

Duads are:—1. *Twin Ovals* (not singly symmetrical on opposite sides), as

$$a^2y^2=(m^2-x^2)(x^2-n^2).$$

2. *Twin Beans* (or Hearts, *Dicuamos*). 3. Pair of Sandals (*Disandalon*): this has always two double tangents parallel, yet the disposition of the four points of contact is not the same in all cases. (They form a rectangle when D=0; they are in lines diverging from the centre when F=0.) 4. Pair of unsymmetrical Lemniscates, which I call *Four Kites*.

Tetrads can only consist of unsymmetrical Ovals, symmetrically disposed.

Of the infinite curves, one very limited class may be called Parabolic, those in

which B=0 and D=0, which reduces the equation to the form $a^2y^2=x^4+2hx^2+k$, when the locus is infinite. It has as curvilinear asymptotes the Proximate twin Parabolas, $a^2y^2=(x^2+h)^2$. The Species are:—1, Twin *Goblets*; 2 (when their vertices unite), Pointed Goblets or Knotted Parabolic Hour-glass; 3, Parabolic Hour-glass; 4, Perforated Hour-glass (with disk in centre); 5, Hollow-bottomed Goblet.

When A=0, we may have asymptotes parallel to the axis of x, and when B=0, to the axis of y. Such curves must be treated apart. When a Quartan Hyperbola is confined between *parallel* asymptotes, I call it an *Arch*, Round-headed or Hollow-headed, as the case may be; they are found, of course, in pairs. A Quartan Hyperbola which is confined within diverging asymptotes like the Conic Hyperbola, I call a *Basin*; when it crosses or otherwise envelopes its diverging asymptotes, I call it a *Cup*. Cups and basins may be Round-bottomed or Hollow-bottomed. Again, a Quartan Hyperbola may lie between an oblique and a vertical asymptote; I then call the Hyperbola itself *Oblique*, equally when it lies between two asymptotes of different systems. Such an Hyperbola may cut one, and only one, asymptote; then I call it *Paratomous*: if it cut both, it is an Oblique Cup. Cups may be Pointed at bottom and unite; they may be also in Contact at bottom, or they may intersect. Vertical and horizontal asymptotes develope other and simpler forms. Conchoids, grouped in pairs, generate one class, and *Arches* another. Arches may intersect, Basins also may intersect sideways; I call this *Paratomy*. Such are the elements (adding only Studs or Conjugate Points) of which all the loci are composed.

Four Hyperbolas, of whatever class, are the utmost that can arise as locus of a Quartan equation; whether in square, each in one quadrant, or as Cross Arches, or as Oblique, or Oblique and Paratomous, or as around and crossing the axes, or between unsymmetrical asymptotes, or it may be Cups instead of Basins.

In the midst of these infinite curves, some one of the Monad or Twin Ovals are often found as Satellites. It must be added that when $AB=D^2$ and the locus is infinite, we find Oblique Parallel Asymptotes, and even, related to them, Oblique Paratomous Arches.

Such is the general description of the *forms*. The *investigation* is simple.

We know that a straight line can cut a Quartan at most in four points. This often shows what forms are impossible.

Put $V=\begin{vmatrix} A & D & E \\ D & B & F \\ E & F & C \end{vmatrix}$, then by Conics we know that if V=0, our general equation will degenerate into the product of two quadratic factors. Besides, if A, B, C are positive and E, F negative, and $E^2=AC$, $F^2=BC$, the equation degenerates into two ellipses.

If $F^2=BC$, and B, F have opposite signs, the curve crosses itself (in a Knot) where $x=0$ and $By^2+F=0$; but if B, F have the same sign, the Knots become Studs. Thus if $E^2=AC$, and $F^2=BC$, but E, F have opposite signs, there are two Knots on one axis and two Studs on the other.

We find where the curve crosses its axis, by putting $Ax^4+2Ex^2+C=0$ when $y^2=0$, and $By^4+2Fy^2+C=0$ when $x^2=0$. Then if AC is positive, E must be negative, if there be any vertex in OX. If AC is negative, there are two vertices.

$$\text{Put}\quad T=Ax^4+2Dx^2y^2+By^4;$$
$$\therefore\ T+(2E^2x^2+2F^2y^2+C)=0$$

is the equation to the curve. When T is essentially positive, the curve is finite. This happens when A, D, B are all of one sign, or when $AB-D^2>0$.

When A=0 and B=0, the curve is finite only when D, E, F are of one sign. If B=0,

$$-y^2=\frac{Ax^4+2Ex^2+C}{2Dx^2+F},$$

and the curve is finite when A, D, F are of one sign. If D and F are of opposite signs, there are asymptotes parallel to y, viz. $2Dx^2+F=0$. Indeed now

$$T=(Ax^2+2Dy^2)x^2;$$

thus, if A and D have opposite signs, $Ax^2+2Dy^2=0$ are oblique asymptotes.

When A, D, B are finite, solve the equation for y^2, regarding B as positive. Put

$$g=D^2-AB,\ h=DF-EB,\ k=F^2-CB;$$
$$\therefore\ By^2+Dx^2+F=\pm\sqrt{(gx^4+2hx^2+k)}.$$

For $D^2-AB>0$, we may assume $g=1$; then for the *upper* sign we get, as Proximate Conic Hyperbola, if D be <1,

$$By_1{}^2+Dx^2+F=x^2+h.$$

If D is negative, we have a second Proximate Conic for the lower sign,

$$By_1{}^2+Dx^2+F=-x^2-h.$$

Of course the asymptotes are $By^2+Dx^2=\pm x^2$, or only $By^2+Dx^2=x^2$.

If $D^2-AB=0$, $g=0$, and the curve is infinite only when h is positive: then *if* D *is negative,*

$$By_1{}^2+Dx^2+F=\pm\sqrt{(2h)}x$$

is two Proximate Conic Hyperbolas, and the asymptotes are oblique and parallel in pairs; they do not pass through the centre, but are equidistant from it.

Evidently if $C=0$ and E, F have opposite signs, the curve crosses itself in the centre; but if $C=0$ and E, F have the same sign, the centre is a mere Stud.

An undulation of the curve implies a double tangent. Such double tangents are always parallel to one axis. [I desire a general proof.] There can be only two pairs parallel to one axis. To ascertain whether there is undulation across OY, put $x^2=0$, and try whether y^2 is there a *maximum* or a *minimum*.

Making x^2 infinitesimal and k positive (which is implied),

$$\sqrt{(k+2hx^2+gx^4)}=\sqrt{k}+\frac{hx^2}{\sqrt{k}}+\frac{gk-h^2}{2k}\cdot\frac{x^4}{\sqrt{k}};$$

thus for upper sign,

$$By^2=(\sqrt{k}-F)+\left(\frac{h}{\sqrt{k}}-D\right)x^2+\frac{gk-h^2}{2k}\cdot\frac{x^4}{\sqrt{k}},$$

whence y^2 is a minimum at $x^2=0$ if $\frac{h}{\sqrt{k}}-D>0$, a maximum if $\frac{h}{\sqrt{k}}-D<0$. Yet when $\frac{h}{\sqrt{k}}=D$, y^2 is a minimum at $x=0$ if $gk-h^2>0$, or a maximum if $gk-h^2<0$. Now $gk-h^2=BV$, and we cannot have $V=0$ without degeneracy. Hence this test is final. Also $h=D\sqrt{k}$ is equivalent to $BE^2-2DEF+CD^2=0$.

If the branch we are investigating is *infinite* and y^2 is a minimum, there is *no* undulation; but if y^2 is a maximum, it begins to decrease, yet must afterwards increase; hence there *is* undulation. On the contrary, if the upper branch be *finite* and y^2 be a maximum, there is no undulation; but there is undulation if y^2 be a minimum.

In general, for tangents parallel to the axis of x, putting $\frac{dy}{dx}=0$, we have the obvious solution $x=0$, when there is a vertex on the axis of y. Besides this, we may have a double tangent where

$$D\sqrt{(gx^4+2hx^2+k)}=gx^2+h,$$

which yields

$$\frac{gx^2+h}{D}=\sqrt{\frac{h^2-gk}{D^2-g}}=\sqrt{(gx^4+2hx^2+k)}=By^2+Dx^2+F.$$

Hence at the points of contact

$$gx^2+h=\pm D\sqrt{-\left(\frac{V}{A}\right)},\ gy^2+h'=\mp\sqrt{(-AV)},$$

if $h'=DE-FA$.

When $T=(\lambda^2x^2-\mu^2y^2)(\rho^2x^2+\sigma^2y^2)$, the curve has oblique asymptotes, $\lambda^2x^2=\mu^2y_0{}^2$. To try whether it ever cut its asymptotes, put $y=y_0$; then at the common point $\lambda^2x^2=\mu^2y^2$, and $2Ex^2+2Fy^2+C=0$. If the x, y hence determined is within the limits of the curve, it does thus cut; if not, it does not.

If $T=(\lambda^2x^2-\mu^2y^2)(\rho^2x^2-\sigma^2y^2)$, there are *two* pair of oblique asymptotes, $\lambda^2x^2=\mu^2y^2$, $\rho^2x^2=\sigma^2y^2$; and by combining *either* of them with the second equation,

$$2Ex^2+2Fy^2+C=0,$$

we decide on Paratomy.

When the general equation is given to us in this form and we desire to find the Proximate Conics, the most direct method is to assume $\mu^2=1$, $\sigma^2=1$, and

$$(y^2-\lambda^2x^2-M)(y^2-\rho^2x^2-N)=T+2(Ex^2+F^2y^2)+MN;$$

whence

$$\left.\begin{aligned}\lambda^2N+\rho^2M&=2E,\\ N+\ \ M&=-2F,\end{aligned}\right\}$$

or

$$M=\frac{2(E+F\lambda^2)}{\rho^2-\lambda^2},$$

$$-N=\frac{2(E+F\rho^2)}{\rho^2-\lambda^2}.$$

Then the Proximate Conics are

$$y_1{}^2-\lambda^2x^2=M,$$
$$y_2{}^2-\rho^2x^2=N.$$

These are closer indications of the infinite branches than the asymptotes. Put $MN=C'$,

$$\therefore \begin{vmatrix} A & D & E \\ D & B & F \\ E & F & C' \end{vmatrix}=0.$$

But in general it is expedient to put $X=gx^4+2hx^2+k$, and study the variations of X in the equation $By^2+Dx^2+F=\pm\sqrt{X}$. In many cases the lower sign is inadmissible; in most it is more restricted than the upper. When we have only the upper, evidently there is no undulation across the axis of x; for y^2 has then but one positive value for any given value of x.

The forms of X are as follows:—

$$\left.\begin{aligned} X_1&=n^2(m^2-x^2),\\ X_2&=(m^2-x^2)(x^2-n^2,)\\ X_3&=(m^2-x^2)x^2,\\ X_4&=(m^2-x^2)(x^2-n^2),\end{aligned}\right\}\quad \left.\begin{aligned} X_5&=n^2(x^2+m^2),\\ X_6&=(x^2+m^2)(x^2+n^2),\\ X_7&=(x^2+m^2)x^2,\\ X_8&=(x^2+m2)^2+n^4,\end{aligned}\right\}\quad \left.\begin{aligned} X_9&=n^2(x^2-m^2),\\ X_{10}&=(x^2-m^2)(x^2+n^2),\\ X_{11}&=(x^2-m^2)x^2,\\ X_{12}&=(x^2-m^2)(x^2-n^2),\\ X_{13}&=(x-m^2)+n^4.\end{aligned}\right\}$$

Remarks on Napier's original Method of Logarithms. *By* Professor PURSER.

On Linear Differential Equations. *By* W. H. L. RUSSELL, *F.R.S.*

The object of this paper was to explain the progress the author is making in his theory for the solution of Linear Differential Equations, especially when the complete integral involves logarithmic functions.

On MacCullagh's Theorem. *By* W. H. L. RUSSELL, *F.R.S.*

This paper was intended to simplify the process given by Dr. Salmon to prove MacCullagh's theorem relative to the focal properties of surfaces of the second order.

Note on the Theory of a Point in Partitions. *By* J. J. SYLVESTER, *F.R.S.*

In writing down all the solutions in positive integers of the indefinite *Equation of Weight*, $x+2y+3z+\ldots=n$, or, in other words, in exhibiting all the partitions

of n any integer greater than zero, it may sometimes be useful to be provided with an easy test to secure ourselves against the omission of any of them. Such a test is furnished by the following theorem:—

$$\Sigma(1-x+xy-xyz\ldots.)=0.$$

thus, *ex. gr.*, if $x+2y+3z+4t+\ldots.=4$, the solutions are five in number, viz.

$$\begin{array}{l}(1)\ y=2,\\ (2)\ t=1,\\ (3)\ x=1\ z=1,\\ (4)\ x=2\ y=1,\\ (5)\ x=4,\end{array}$$

the values of the omitted variables in each solution being zero. The five corresponding values of $1-x+xy\ldots.$ are

$$1,\ 1,\ 0,\ 1,\ -3,$$

whose sum is zero.

The theorem may be proved immediately by expressing the denumerant (which is zero) of the simultaneous equations

$$\left\{\begin{array}{l}x+2y+3z+\ldots=n,\\ x+y+z+\ldots\ldots=0,\end{array}\right\}$$

in terms of simple denumerants according to the author's general method, or by virtue of the known theorem,

$$(1-t)(1-t^2)(1-t^3)\ldots.$$
$$=1-\frac{t}{(1-t)}+\frac{t^3}{(1-t)(1-t^2)}-\frac{t^6}{(1-t)(1-t^2)(1-t^3)}+\frac{t^{10}}{(1-t)(1-t^2)(1-t^3)(1-t^4)}+\ldots$$

This gives at once the equation

$$\frac{1}{(1-t)(1-t^2)(1-t^3)\ldots}-\frac{t}{(1-t)^2(1-t^2)(1-t^3)\ldots}+\frac{t^3}{(1-t)^2(1-t^2)^2(1-t^3)\ldots}\ldots=1.$$

Hence the coefficient of t^n in the above written series for all values of n other than zero is zero. But it will easily be seen that the coefficient of t^n in the first term is $\Sigma 1$, in the second term Σx, in the third Σxy, &c.; so that $\Sigma(1-x+xy\ldots.)=0$, as was to be shown. Thus we have obtained for the problem of indefinite partition a new algebraical unsymmetrical test supplementing the well-known pair of transcendental symmetrical tests expressible by the equations

$$\Sigma\frac{\Pi(x+y+z\ldots)}{\Pi x\,\Pi y\,\Pi z\ldots}=2^{n-1},$$
$$(\Sigma-)^{x+y+z\ldots}\frac{\Pi(x+y+z\ldots)}{\Pi x\,\Pi y\,\Pi z\ldots}=0\,*.$$

* Subject of course to the conditions that n is greater than 1. If $x, y, z, \ldots, \omega$ represents any solution in positive integers of the equation

$$x+2y+3z\ldots+r\omega=r,$$

it is easy to see that

$$\Sigma(-)^{x+y+\ldots.+\omega}\frac{\Pi(x+y+\ldots.+\omega)}{\Pi x\,\Pi y\ldots.\,\Pi\omega}=1,\ -1,\ \text{or}\ 0,$$

according as n, in regard to the modulus $r+1$, is congruent to 0, 1, or neither to 0 nor 1, for the left-hand side of the equation is obviously the coefficient of x^n in the development of

$$\frac{1}{1+x+x^2\ldots+x^r},\quad i.e.\quad\frac{1-x}{1-x^{r+1}}.$$

On making $r=\infty$, this theorem becomes the one in the text. It obviously affords a remarkable pair of independent arithmetical quantitative criteria for determining whether or not one number is divisible by another.

The identity employed in the text is only a particular case of Euler's identity,

$$(1+tz)(1+t^2z)(1+t^3z)\ldots=1+\frac{tz}{(1-t)}+\frac{t^3z^2}{(1-t)(1-t^3)}+\ldots,$$

which is tantamount to affirming that the number of partitions of n into r distinct integers is the same as the number of partitions of n into any integers none greater than r, in which all the integers from 1 to r appear once at least. It has not, I believe, been noticed that these two systems of partitions are conjugate to each other, each partition of the one system having a correspondent to it in the other. The mode of passing from any partition to its correspondent is by converting each of its integers into a horizontal line of units, laying these horizontal lines vertically under each other, and then summing the columns. Thus, *ex. gr.*, 3, 4, 5 will be first expanded horizontally into

$$\begin{array}{lllll} 1 & 1 & 1, & & \\ 1 & 1 & 1 & 1, & \\ 1 & 1 & 1 & 1 & 1, \end{array}$$

and then summed vertically into

$$3 \quad 3 \quad 3 \quad 2 \quad 1.$$

This is the method employed by Mr. Ferrers to show that the number of partitions of n into r, or a less number of parts, is the same as the number of partitions of n into parts none greater than r, and is, in fact, only a generalization of the method of intuitive proof of the fact that

$$m\times n=n\times m,$$

the difference merely being that we here deal with a parallelogram separated into two conterminous parts by an irregularly stepped boundary—one filled with units, the other left blank, instead of dealing with one entirely filled up with units.

On the General Canonical Form of a Spherical Harmonic of the n*th Order.* *By* Sir W. Thomson, *LL.D., D.C.L., F.R.SS. L. & E.*

Let $H_i\ (x, y, z)$, $H'_i\ (x, y, z)\ \ldots$, or for brevity H, H′, &c., denote $2i+1$ independent spherical harmonics of degree i, that is to say, homogeneous functions each fulfilling the Laplace's equation

$$\frac{d^2H}{dx^2}+\frac{d^2H}{dy^2}+\frac{d^2H}{dz^2}=0. \qquad (1)$$

The formula

$$AH+A'H',\ \&c., \qquad (2)$$

where A, A′ are constants, is a general expression for the harmonic of degree i; but it is not a "canonical" expression. Borrowing this designation from Mr. Clifford's previous paper, we may define as *canonical constituents* for the general spherical harmonic of degree i, any set of particular distinct harmonics fulfilling the following conditions:—

$$\iint HH'\,d\sigma=0,\ \iint H'H''d\sigma=0,\ \&c. \qquad (3)$$

where $\iint d\sigma$ denotes integration over any spherical surface having the origin of coordinates for centre. Supposing now that H, H′ . . . actually fulfil these conditions, let it be required to find, if possible, another canonical form ($\mathfrak{H}, \mathfrak{H}', \ldots$).

Try

$$\mathfrak{H}=AH+A'H'+\&c.,$$
$$\mathfrak{H}'=BH+B'H'+\&c.$$

Then, (3) being taken into account, $\iint \mathfrak{H}\mathfrak{H}'\,d\sigma=0$ gives

$$AB+A'B'+\&c.=0.$$

Hence the normal linear transformation, with $(2i+1)^2$ coefficients

$$\begin{array}{l} A, A', A'', \ldots . \\ B, B', B'', \ldots . \\ C, C', C'', \ldots . \end{array}$$

subject to the $i\ (2i+1)$ equations

$$AB+A'B'+A''B''=0$$
$$AC+A'C'+A''C''=0$$
$$BC+B'C'+B''C''=0$$
$$\cdots\cdots\cdots$$

gives, from any one canonic group, another indeterminately. To find the degree of indeterminateness, let absolute magnitudes in canonical forms be ruled by the conditions

$$\iint H^2\,d\sigma=\iint H'^2 d\sigma=..=1,$$
$$\iint \mathfrak{H}^2\,d\sigma=\iint \mathfrak{H}'^2\,d\sigma=..=1,$$

we have therefore

$$A^2+A'^2+A''^2+...=1,$$
$$B^2+B'^2+B''^2+...=1,$$

as in the ordinary transformation of rectangular axes in three dimensions. These $2i+1$ equations with the $i\ (2i+1)$ previous, amount in all to $(i+1)\ (2i+1)$ equations of condition among $(2i+1)^2$ coefficients, leaving $i\ (2i+1)$ independent variables.

The only canonical form hitherto generally recognized is that of Laplace; consisting* of $2i+1$ polar harmonics, of which 1 is zonal, $2\ (i-1)$ are tessaral, and 2 are sectorial. In the discussion which followed Mr. Clifford's paper on this form, I remarked that it seemed to be a singular case of the general canonic; notably singular in this respect, that for any one of its constituents the nodal cone consists of circular cones having a common axis and planes through this axis. The nodal cone of any spherical harmonic of degree i is an algebraic surface of degree $2i+1$, and I proposed the question, can canonical forms not be found in which the nodal cone of each constituent is not resolvable into circular cones and planes? This question is answered by the present communication.

[A diagram was roughly sketched on the board, to illustrate the nodal cone of a harmonic differing infinitely little from a tessaral harmonic; which, with $2i$ others differing infinitely little from the other $2i-3$ tessaral, the two sectorial, and the zonal, constituting the polar canonic, would constitute a generalized canonic.]

General Physics.

Account of Experiments upon the Resistance of Air to the Motion of Vortex-rings. By Robert Stawell Ball, *A.M., Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.*

The experiments, of which the following is an abstract, were carried out with the aid of a grant from the Royal Irish Academy. A paper containing the results has been laid before the Academy.

The author proposed to bring this subject before the Association in order to elicit discussion. He would greatly value any suggestions as to the direction in which future experimental researches would be likely to prove fruitful. Such suggestions, though acceptable from all sources, would come with peculiar usefulness from those who are conversant with the profound hydrodynamical problems of vortex motion.

A brief account of one series of the experiments, and a Table embodying them, will be given.

Air-rings, 9 inches in diameter, were projected from a cubical box, each edge of which is 2 feet. The use of this box was suggested by Professor Tait (see a

* Thomson and Tait's 'Natural Philosophy,' § 781.

paper by Sir William Thomson, Phil. Mag. July 1867; also a paper by the Author, Phil. Mag. July 1868). The blows were delivered by means of a pendulum called the striker, which, falling from a constant height, ensured that the rings were projected with a constant velocity. In the experiments described in the present series, this velocity was somewhat over 10 feet per second. The pendulum was released to deliver the blow from a pair of forceps, each jaw of which was in connexion with a pole of a battery. After the ring had traversed a range varied from 2 inches to 20 feet, it impinged upon a target. The blows upon the target closed the circuit, which had been opened at the release of the striker. An electric chronoscope (devised, it is believed, by Wheatstone) measured the interval of time between the release of the striker and the impact upon the target.

The target was placed successively at distances of 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 feet from the orifice of the box. Not less than ten observations of the time were taken at each range. The probable error of the mean time at each range is in every case less than 1 per cent. of the whole amount. A special series of experiments, which need not be described, determined the value of the chronoscope readings in seconds.

The observations are next represented in a curve, of which the abscissæ are the ranges, and the ordinates the corresponding mean chronoscope readings. By drawing tangents to this curve, the velocity of the ring at its different points is approximately found.

A second projection is made in which the abscissæ are the ranges and the ordinates are the velocities; the points thus determined are approximately in a straight line.

It follows that the rings are retarded as if acted upon by a force proportional to the velocity, and an approximate value of the numerical coefficient becomes known.

A more accurate value having been determined by the method of least squares, the results are embodied in the following Table (p. 28), of which a description is first given. The Roman letters refer to the several columns of the Table.

I. contains a series of numbers for convenience of reference.

II. It was found that the motion of the ring in the immediate vicinity of the box was influenced by some disturbing element. The zero of range was therefore taken at a point 4 feet distant from the orifice. This column contains the ranges.

III. The interval between the release of the striker and the arrival of the ring at a point 4 feet from the orifice is 6·5 chronoscopic units, or about 0·93 second. This constant must be subtracted from the mean readings of the time, in order to reduce the zero epoch to the instant when the ring is 4 feet from the orifice. This column contains the mean readings of the chronoscope corrected by this amount.

IV. When the ranges are taken as abscissæ, and the corresponding times as ordinates, it is found that a curve can be drawn through or near all the points thus produced. To identify the points with the curve, small corrections are in some cases required. These corrections are shown in column IV. In the case of experiment 5 the correction amounts to 0·7; this is about 0·09 second. The magnitude of this error appears to show that some derangement, owing possibly to a current of air or other source of irregularity, has vitiated this result. For the sake of uniformity, however, the corrected value has been retained.

V. This column merely contains the corrected means, as read off upon the curve determined by the points.

VI. The value of the chronoscope unit after the first few revolutions is

$$0{\cdot}1288 \text{ second,}$$

with a probable error of 0·0002 second. By means of this factor the corrected means in column V. are evaluated in seconds in column VI.

VII. This column contains the time calculated on the hypothesis that the rings are retarded as if acted upon by a force proportional to the velocity, the coefficients being determined by the method of least squares; the formula is

$$t = 9{\cdot}016 - 6{\cdot}25 \log (27{\cdot}7 - s).$$

TABLE of Experiments, showing the retardation which a Vortex-ring of air experiences when moving through air at the same temperature and pressure. The vortex-ring is 9 inches in diameter, and has an initial velocity of 10·2 feet per second. The retarding force is proportional to the velocity; and after 2·24 seconds the ring has moved 16 feet, and its velocity is reduced to 4·3 feet per second.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.
Reference number.	Distance of target from orifice, minus 4 feet, s.	Mean corresponding reading of chronoscope, minus 6·5.	Correction deduced by graphical construction.	Corrected value of mean chronoscopic reading.	Equivalent time, in seconds.	Calculated time by formula $t=9{\cdot}016-6{\cdot}25\log(27{\cdot}7-s)$.	Difference between calculated and observed time.	Approximate velocity, deduced from graphical construction.	True velocity, calculated by $\frac{ds}{dt}=0{\cdot}368(27{\cdot}7-s)$.	Retarding force, calculated by $-\frac{d^2s}{dt^2}=0{\cdot}136(27{\cdot}7-s)$.
1.	2 feet	1·6	0·0	1·6	0·21 secs.	0·20 secs.	−0·01	9·3	9·5	3·5
2.	4 "	3·4	−0·1	3·3	0·43 "	0·42 "	−0·01	8·4	8·7	3·2
3.	6 "	5·4	−0·2	5·2	0·67 "	0·66 "	−0·01	7·7	8·0	3·0
4.	8 "	7·3	0·0	7·3	0·93 "	0·92 "	−0·01	7·3	7·2	2·7
5.	10 "	10·2	−0·7 !	9·5	1·23 "	1·22 "	−0·01	6·4	6·5	2·4
6.	12 "	12·0	−0·1	11·9	1·54 "	1·54 "	0·00	5·9	5·8	2·1
7.	14 "	14·5	+0·3	14·8	1·91 "	1·91 "	0·00	5·2	5·0	1·9
8.	16 "	18·2	−0·1	18·1	2·33 "	2·34 "	+0·01	4·4	4·3	1·6

VIII. This column shows that the difference between the corrected mean time and the calculated time in no case exceeds

0·01 second.

IX. The approximate velocities, deduced by drawing tangents to the curve.

X. The true velocities, calculated from the formula

$$\frac{ds}{dt}=0{\cdot}368(27{\cdot}7-s).$$

XI. The retarding force, calculated by

$$-\frac{d^2s}{dt^2}=0{\cdot}136(27{\cdot}7-s).$$

Experiments on Vortex-rings in Liquids. *By* H. DEACON.

On Units of Force and Energy. *By* Professor J. D. EVERETT, *F.R.S.E.*

The object of the paper was to urge the necessity of giving names to *absolute* units of force and energy, that is, units not varying with locality, like the gravitation units vulgarly employed (pound, foot-pound, &c.), but defined by reference to specified units of length, mass, and time, according to the condition that unit force acting on unit mass produces unit acceleration.

The author proposed that the units of force and of energy (or of work), thus related to the metre, gramme, and second, be called respectively the *dyne* and the *pone* (δύναμις, πόνος), and that the names *kilodyne*, *megadyne*, *kilopone*, *megapone* be employed to denote a thousand and a million dynes and pones. The megadyne and megapone will thus be the units of force and energy related to the metre, the tonne, and the second.

He also proposed that the units of force and energy related to the foot, the pound, and the second be called respectively the *kinit* and the *erg* *.

On the Corrosion of Copper Plates by Nitrate of Silver. *By* J. H. GLADSTONE, *F.R.S.*, and ALFRED TRIBE, *F.C.S.*

In some recent experiments in chemical dynamics, the authors had occasion to study the action of nitrate of silver on copper plates in various positions. They observed that when the plate was vertical there was rather more corrosion at the bottom than at the top. This is easily accounted for by the upward current, which flows along the surface of the deposited crystals, and which necessitates a movement of the nitrate-of-silver solution towards the copper plate especially impinging on the lower part. It was also found that when the copper plate was varnished on one side it produced rather more than half the previous decomposition, and was most corroded at the edges of the varnish. By making patterns with the varnish, this edge action became very evident. This was explained by the fact that the long crystals of silver growing out from the copper at the borders can spread their branches into the open space at the side, and so draw their supply from a larger mass of solution than the crystals in the middle can do; and increased crystallization of silver means increased solution of copper. This was proved by making the varnish a perpendicular wall instead of a thin layer, when the greater corrosion was not obtained. In a plate completely surrounded with liquid, the greatest growth of crystals is also evidently from the angles. It was likewise observed that if a vertical plate be immersed, the lower part in nitrate of copper, and the upper part in nitrate of silver, there is greater corrosion about the point of junction. This was attributed to the greater conduction of the stronger liquid.

Some Remarks on Physics. *By* M. JANSSEN.

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* Since the reading of the paper, a Committee has been appointed by the Association "to frame a nomenclature of absolute units of force and energy."

On Democritus and Lucretius, a Question of Priority in the Kinetical Theory of Matter. By T. M. LINDSAY *and* W. R. SMITH.

Physicists who have recently called attention to the anticipation of modern doctrines as to the ultimate nature of matter by the ancient atomists, have looked too exclusively to Epicurus and his expositor Lucretius, to the neglect of Democritus and Leucippus. Democritus had no such expositor as Lucretius, but his main views are accessible in the fragments collected by Mullach, and in the well-known references of Aristotle, Simplicius, and Laertius. With the help of these sources, the paper sketches the main features of the earliest atomic theories. The following are leading points:—

Democritus and Leucippus trace the variety of phenomena to three primitive differences in the ultimate elements of nature, viz. differences (1) in Figure, *σχῆμα*, as between **A** and **N**; (2) in Order, *τάξις*, as **AN**, **NA**; (3) in Position, *θέσις*, as **Z**, **N** [Arist. Met. A. 4]. From the motion *in vacuo* of atoms with these primary differences, the whole variety of nature is deduced, generation and corruption being merely syncretion and division (*σύγκρισις, διάκρισις*) [Ar. De Gen. et Cor. i. 8, i. 2, Phys. viii. 9]. All atoms have the same density and the same *ὁρμὴ τῆς φορᾶς* (specific gravity ?) [Ar. De Cœlo, i. 7, Theophrastus De Sensu, 71]. Hence all tend to fall in one downward direction *; but being ignorant of the law of inertia, Democritus supposes that the larger atoms fall faster, impinge on lighter particles, and produce a vortex motion (*δίνη*). In this vortex similars come together and cohere, lighter particles go to the surface, and at length worlds (*κόσμοι*) are generated [Diog. Laertius, ix. 31]. Epicurus differs from Democritus mainly by maintaining that all atoms have equal and invariable downward velocities, and come into collision only by fortuitous automatic deflection from the line of fall. The first half of this theory *looks* like the first law of motion, but is really as far from being in harmony with the laws of acceleration and other known truths as the earlier view. As physicists, therefore, Epicurus and Lucretius made no advance on Democritus, while by mixing up with legitimate physical speculation the incongruent *metaphysical* notion of chance (not the *mathematical* notion of chance, which plays a part in the modern kinetic theory of gases), they produced that hybrid of physics and metaphysics, a materialistic philosophy. It was by adopting the Epicurean doctrine of chance that Gassendi, the first of modern atomists, became also the father of modern materialism.

Speculations on the Continuity of the Fluid State of Matter, and on Relations between the Gaseous, the Liquid, and the Solid States. By Prof. JAMES THOMSON, *LL.D.*

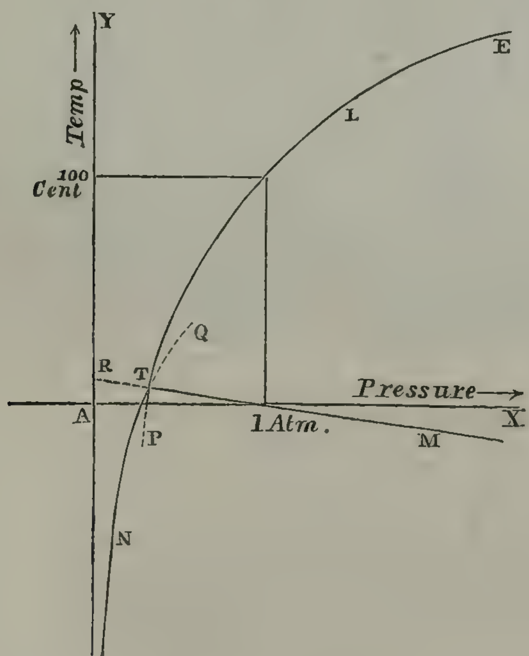
Through the recent discovery of Dr. Andrews on the relations between different states of fluid matter, a difficulty in the application of our old ordinary language has arisen. He has shown the existence of continuity between what is ordinarily called the liquid state and what is ordinarily called the gaseous state of matter. He has shown that the ordinary gaseous and ordinary liquid states are only widely separated forms of the same condition of matter, and may be made to pass into one another by a course of continuous physical changes presenting nowhere any interruption or breach of continuity. If, now, there be no distinction between the liquid and gaseous states, is there any meaning still to be attributed to those two old names, or ought they to be abandoned, and the single name *the fluid state* to be substituted for them both? The answer must be that in speaking of the whole continuous state we have now to call it simply *the fluid state*; but that there are two regions or parts of it, meeting one another sharply in one way, and merging gradually into one another in a different way, to which the names *liquid* and *gas* are still to be applied. We can have a substance existing in two fluid states different in density and other properties, while the temperature and pressure are the same in both: and we may then find that an introduction or abstraction of heat without change of temperature or of pressure will effect the change from the one state to the other, and that the

* Cf. the argument in Zeller, Phil. der Griechen, i. 913, ff.

change either way is perfectly reversible. When we thus have two different states present together in contact with one another, we have a perfectly obvious distinction, and we can properly continue to call one of them a liquid state and the other a gaseous state of the same matter. The same two names may also reasonably be applied to regions or parts of the fluid state extending away on both sides of the sharp or definite boundary, wherever the merging of the one into the other is little or not at all apparent. If we denote geometrically all possible points of temperature and pressure jointly, by points spread continuously in a plane surface, each point in the plane being referred to two axes of rectangular coordinates, so that one of its ordinates shall represent the pressure and the other the temperature denoted by that point, and if we mark all the successive boiling- or condensing-points of pressure and temperature as a continuous line on this plane, this line, which may be called *the boiling-line*, will be a separating boundary between the regions of the plane corresponding to the ordinary liquid state and those corresponding to the ordinary gaseous state. But by consideration of Dr. Andrews's experimental results (Phil. Trans. 1869), we may see that this separating boundary comes to an end at a point of temperature and pressure which, in conformity with his language, may be called the *critical point* of pressure and temperature jointly; and we may see that from any ordinary liquid state to any ordinary gaseous state the transition may be gradually effected by an infinite variety of courses passing round the extreme end of the boiling-line.

Fig. 1 is a diagram to illustrate these considerations and some allied considerations to which they lead in reference to transitions between the three states, the

Fig. 1.



gaseous, the liquid, and the solid. This figure is intended only as a sketch to illustrate principles, and is not drawn according to measurements for any particular substance, though the main features of the curves shown in it are meant to relate in a general way to the substance of water, steam, and ice. A X and A Y are the axes of coordinates for pressures and temperatures respectively; A, the origin, being taken as the zero for pressures and as the zero for temperatures on the Centigrade scale. The curve L represents the boiling-line. This terminates towards one direction in the *critical point* E; it passes in the other direction to T, the point of pressure

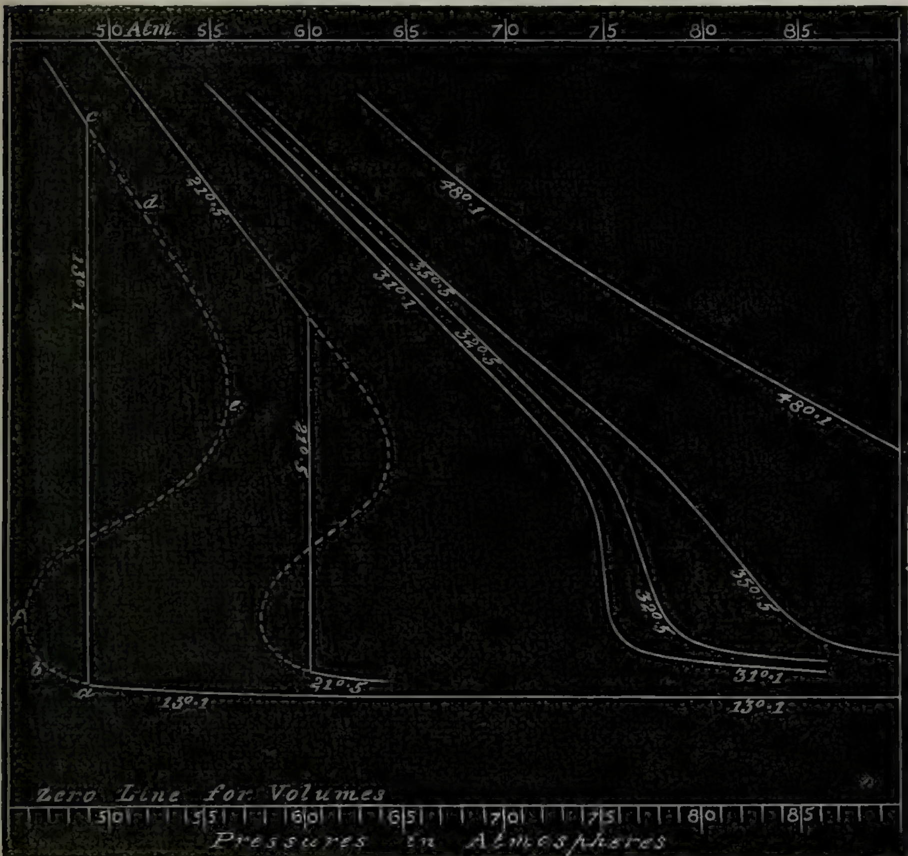
and temperature where solidification sets in. This point T is to be noticed as a remarkable point of pressure and temperature, as being the point at which alone the substance, pure from admixture with other substances, can exist in three states, solid, liquid, and gaseous, together in contact with one another. In making this statement, however, the author wishes to submit it subject to some reserve in respect to conditions not as yet known with perfect certainty. He observes that we might not be quite safe in assuming that the melting-point of ice solidified from the gaseous state is the same as the melting-point of ice frozen from the liquid state, and in making other suppositions, such as that the same quantity of heat would become latent in the melting of equal quantities of ice formed in these two ways. Such considerations as these into which we are forced if we attempt to sketch out the course of the boiling-line, and to examine along with it the corresponding boundary-lines between liquid and solid and between gas and solid, may be useful in suggesting questions for experimental and theoretical investigation which may have been generally overlooked before. Proceeding, however, upon assumptions such as usually are tacitly made, of identity in the thermal and dynamic conditions of pure ice solidified in different ways, the author points out that we must suppose the three curves (namely, the line between gas and liquid, the line between liquid and solid, and the line between gas and solid) to meet in one point, shown at T in the figure. This point of pressure and temperature for any substance may then be called *the triple point* for that substance. In the figure the line T M represents the line between liquid and solid. It is drawn showing in an exaggerated degree the lowering of the freezing temperature of water by pressure, the exaggeration being necessary in order to allow small changes of temperature to be perceptible in the diagram. The line T N represents the line between the gaseous and the solid states of water substance. The two curves T L and T N, one between gas and liquid and the other between gas and solid, have been constructed for water substance through a great range of temperatures and pressures by Regnault, from his experiments on the pressure of saturated aqueous gas at various temperatures above and below 0° Centigrade*. He has represented and discussed his results above and below the temperature at which the water freezes (which in strictness is not 0° C., but is the freezing temperature of water in contact with no atmosphere except its own gas), as if one continuous curve could extend for both. As brought out experimentally, indeed, they present so little appearance of any discontinuity that the distinctness of the two curves from one another might readily escape notice in the consideration of the experimental results. Prof. Thomson points out, however, that the range from temperatures below to temperatures above freezing comprises what ought to be regarded as two essentially distinct curves meeting one another in the point T; and he further suggests that continuations of these curves, sketched in as dotted lines T P and T Q, may have some theoretical or practical significance not yet fully discovered. He thinks it likely that out of the three curves at least the one, M T, between liquid and solid may have a practically attainable extension past T, as shown by the dotted continuation T R. Various known experiments seem to render this supposition tenable, whether the condition supposed may have been actually realized in experiments hitherto or not. He thinks, too, that there is much reason to suppose that the curve L T between gas and liquid has a practically attainable extension past T, as shown by the dotted continuation T P.

In reference to the continuity of the liquid and gaseous states, Prof. Thomson showed a model in which Dr. Andrews's curves for carbonic acid are combined in a curved surface, obtained from them, which is referred to three axes of rectangular coordinates, and is formed so that the three coordinates of each point in the curved surface shall represent, for any given mass of carbonic acid, a pressure, a temperature, and a volume, which can coexist in that mass. This curved surface shows in a clear light the abrupt change or breach of continuity at boiling or condensing, and the gradual transition round the extreme end of the boiling-line. Using this model and a diagram of curves represented here in fig. 2, the author explained a view which had occurred to him, according to which it appears probable that although there be a practical breach of continuity in crossing the line of boiling-points from liquid to gas, or from gas to liquid, there may exist, in the nature of

* Mémoires de l'Académie des Sciences, 1847, pl. viii.

things, a theoretical continuity across this breach, having some real and true significance. The general character of this view may readily be seen by a glance at fig. 2, in which Dr. Andrews's curves are shown by continuous lines (not dotted), and curved reflex junctions are shown by dotted lines connecting those of Dr. An-

Fig. 2.



drews's curves which are abruptly interrupted at their boiling- or condensing-points of pressure. It is to be understood that each curve relates to one constant temperature, and that pressures are represented by the horizontal ordinates, and corresponding volumes of one mass of carbonic acid constant throughout all the curves are represented by the vertical ordinates. The author points out that, by experiments of Donny, Dufour, and others *, we have already proof that a continuation of the curve for the liquid state past the boiling stage for some distance, as shown dotted in fig. 2, from *a* to some point *b* towards *f*, would correspond to states already attained. He thinks we need not despair of practically realizing the physical conditions corresponding to some extension of the gaseous curve such as from *c* to *d* in the figure. The overhanging part of the curve from *e* to *f* he thinks may represent a state in which there would be some kind of unstable equilibrium; and so, although the curve there appears to have some important theoretical significance, yet the states represented by its various points would be unattainable throughout any ordinary mass of the fluid. It seems to represent conditions of coexistent temperature, pressure, and volume, in which, if all parts of a mass of fluid were placed, it would be in equilibrium, but out of which it would be led to rush, partly into the rarer state of gas, and partly into the denser state of liquid, by the slightest inequality of temperature or of density in any part relatively to other parts.

* Donny, Ann. de Chimie, 1846, 3rd series, vol. xvi. p. 167; Dufour, Bibliothèque Universelle, Archives, 1861, vol. xii.

Observations on Water in Frost Rising against Gravity rather than Freezing in the Pores of Moist Earth. By Professor JAMES THOMSON, *LL.D.*

In this paper Prof. Thomson, in continuation of a subject which he had brought before the British Association at the Cambridge Meeting in 1862*, on the Disintegration of Stones exposed to Atmospheric Influences, adduced some remarkable instances which he had since carefully observed. In one of these, observed by him in February 1864, he showed that water from a pond in a garden had in time of frost raised itself to heights of from four to six inches above the water surface-level of the pond by permeating the earth-bank, formed of decomposed granite, which it kept thoroughly wet, and out of the upper surface of which it was made to ascend by the frost, so as to freeze as columns of transparent ice, rather than that it would freeze in the earth-pores. The columns were arranged in several tiers one tier below another, the lower ones having been later formed than those above them, and having pushed the older ones up. From day to day during the frost the earth remained unfrozen, while a thick slab of columnar ice, made up of successive tiers of columns, formed itself by water coming up from the pond and insinuating itself forcibly under the bases of the ice-columns so as to freeze there, pushing them up, not by hydraulic pressure, but on principles which, while seeming not to have been noticed previously to their having been suggested by the author at the Cambridge Meeting, appear to involve considerations of scientific interest, and to afford scope for further experimental and theoretical researches. In the case referred to, the remarkable phenomenon showed itself very clearly, of water passing from a region of less than atmospheric pressure in the wet pores of the earth, into a place in the base of the columns where it was subject to more than atmospheric pressure, and subject also to stresses unequal in different directions, from its being loaded with the mass of ice and also with some gravel or earthy substances above it; and this action went on rather than that the water would freeze in the pores of the moist earthy bottom on which the columns stood, and which was above the water surface-level of the pond.

ASTRONOMY.

Note on the Secular Cooling and the Figure of the Earth. By Prof. CLIFFORD.

Observations on the Parallax of a Planetary Nebula. By Dr. GILL.

On the Coming Solar Eclipse. By M. JANSSEN.

On the Recent and Coming Solar Eclipses. By J. NORMAN LOCKYER, *F.R.S.*

On the Construction of the Heavens. By R. A. PROCTOR, *B.A.*

On Artificial Coronas. By Professor OSBORNE REYNOLDS.

On a Method of Estimating the Distances of some of the Fixed Stars. By H. FOX TALBOT, *LL.D., F.R.S.*

The method proposed in this paper for ascertaining the distances of the stars applies only to binary systems, which are not too faint or too close to be well observed. It has this peculiarity, that it can be applied to remote stars with as much accuracy as to nearer ones, always supposing that such remote stars are still bright

* Brit. Assoc. Rep. 1862, Trans. of Sect. p. 35.

enough to allow of accurate observation; whereas the method of determining the distance of a star by its parallax becomes more difficult as the distance of the star increases, notwithstanding any brightness which it may have.

The method now proposed is founded on that of spectral analysis. I suppose a certain ray, which I will call X, to be chosen as the standard ray, and to be carefully observed at various times in each of the stars of a binary system during an interval of some years. The orbit described by the stars around their common centre of gravity must not lie in a plane perpendicular to the visual ray joining those stars and the earth, nor must it approach that position too nearly, otherwise the true result would be masked by the errors of observation. The simplest case is that of two stars, equal in mass and brightness, and revolving in circles about their common centre of gravity. Supposing such a system of two stars to exist, the most favourable case is when the plane of their motion passes through the earth. If it does so, the stars will appear to move in straight lines. Supposing them to be, when first observed, at their greatest elongation, they will approach each other with an increasing apparent velocity, varying as the sine of the time (or circular arc described) until they come into apparent conjunction, when one star will be hidden by the other for a certain time, after which they will recede from each other in like manner as they had approached. But the observer would not be able to say with certainty which of the two stars was nearest to him, since the same phenomena would be presented if the distances of the two stars were interchanged, and at the same time the direction of their motions reversed. Now suppose the method to be applied which I have proposed. At the time of their conjunction, or near it, neither star would be approaching the earth, consequently the observed deviation of the ray X (if any) from its normal position would be due to the *proper motion* of the system of the two stars relatively to the earth, which is a constant quantity to be allowed for in all other observations. Now suppose another set of observations to be made at the time of the greatest elongation of the two stars. At that time each of the stars is apparently stationary, but in fact one of them is approaching and the other receding from the earth with a maximum velocity. The observed deviation of the ray X will therefore be different in the spectra of the two stars, and (allowance having been made for the proper motion of the system) it will appear at once which of the two stars is approaching the earth, and the question of its direct or retrograde orbit will be resolved. At the same time the distance of the two stars from the earth will result from the calculation. It will be well, perhaps, to take a hypothetical example, which will show how this element results from observation.

I suppose, then, that observation has shown:

(1) The period of one complete revolution of the binary star round its centre of gravity to be *fifty years.*

(2) The greatest elongation of the stars to be *ten seconds.*

(3) And at the time of this greatest elongation the deviation of the ray X to be such as to prove that one of the stars is then approaching the earth at the rate of *ten miles per second,* and the other star receding from the earth at the same rate. And this will evidently be their true velocity in their orbit.

Now 50 years =1,577,880,000 seconds, and therefore since each star moves in its orbit at the rate of ten miles per second, it describes in the course of one whole revolution of 50 years a circle of 15,778,800,000 miles in circumference. The radius of this circle is the distance of the star from the common centre of gravity, and therefore the diameter of the circle is the distance of the two stars from each other (which in the hypothetical example I have selected is constant). This diameter will be found to be about equal to 54 radii of the earth's orbit. Now, when the stars were at their greatest elongation, observation showed their angular distance to be *ten seconds.* Consequently we have only to calculate at what distance from the earth a length of 54 radii would subtend an angle of 10″, and we find that this would occur at a distance of 1,113,500 radii. Such, then, is the distance of the binary star from the earth, namely, 1,113,500 times the distance which separates the earth from the sun.

So simple a case as the hypothetical one which I have here calculated is, indeed, not likely to occur in practice; most cases would require a greater complexity of

calculation, but the principles involved would be the same. When the distances and positions of the two components of a binary star have been carefully observed by astronomers for a certain number of years, it has been found possible in many instances to determine the elements of their orbit, its ellipticity, the inclination of its plane to the ecliptic, the time of one complete revolution, the apparent maximum elongation, &c. &c. But the distance of the double star from the earth has hitherto remained unknown, because that is dependent upon the *real* size of the orbit, and observation (without the spectroscope) gives only the *apparent* size of it. Knowing the elements of the orbit we can, indeed, calculate the velocity of either of the stars in the direction of the earth at any moment, *relatively* to that which it has at any other moment. But the determination of the *absolute* velocity requires the distance of the stars from the earth to be known. Now a few observations (if perfectly correct) of the deviation of the ray X supply this wanting element, viz. the actual velocity at the time of observation, and likewise enable us, as I have already explained, to eliminate the proper motion of the double star. This might be sometimes difficult, but geometrical considerations, quite in harmony with those now employed by astronomers to determine the other elements of the binary system, would undoubtedly effect this also.

In what I have written above, I have supposed great precision in the observations—greater, no doubt, than would be practicable with the optical means *now* in use; but this makes no difference in the *theory* of the subject, which for a certain time may be allowed to pass ahead of its practical realization. It will doubtless be remembered that the method of determining the sun's distance by means of a transit of Venus was proposed by James Gregory in his 'Optica Promota,' and by Halley in his 'Catalogus Stellarum Australium,' nearly 100 years before an opportunity offered of testing it by an actual observation.

On the Nutoscope, an Apparatus for showing Graphically the Curve of Precession and Nutation. By Professor CHARLES V. ZENGER.

In the case of a rapidly revolving solid body two different cases may occur, the mass of the solid body being quite uniformly distributed around the axis of rotation, or, on the contrary, the uniformity being destroyed by the accumulation of matter on one side of the axis.

In the first instance the centrifugal force will act symmetrically on opposite sides of the solid body in rotation, and be in equilibrium. It then gives rise to the phenomenon of a free axis; that is to say, the axis of rotation steadily holds its position during the rotation, because the particles of the body will also have the tendency to retain their position while the motion is going on with sufficient speed.

These facts may best be shown by Fessel's apparatus, called the gyroscope, in which a circular disk is put in rapid rotation round an axis freely movable in every direction.

If there is a force acting only on one side, for instance a weight pressing on the axis, or an impulse given to it, the axis will show a lateral motion, and describes a cone, or at its extremity a circle.

But if there is on the disk itself an unequal distribution of the mass, which is produced by fastening a small circular disk or sheet of paper with an excentric hole upon the axis, the motion becomes more complicated; and if the velocity be considered uniform for the short time required for the axis to describe a circle, there will be an additional lateral motion produced by the adhering paper sheet disturbing the motion, and a small ellipse will be described by the end of the axis revolving upon the circle, as is shown in the diagram traced on blackened paper by the top of such an apparatus.

The greater the mass of the disturbing paper sheet, and the more the speed of the motion diminishes, the larger becomes the diameter of the ellipse described by the top, and the more disturbed are its revolutions on the periphery of the circle, both axis of the ellipses becoming much larger. Diminution of the speed originates, instead of the circular motion of the top, a spiral motion, and the effect is

that the velocity of the disk's motion decreasing, the top no longer describes a circle, but a continuous spiral line, on which the small ellipse revolves.

These motions, however complicated they may be, may be graphically shown by holding a blackened paper to the top of the axis of the apparatus, and causing it to approach steadily, when the axis becomes more inclined by the diminution of the velocity.

To do this more easily and with more precision, near the rotating disk is placed a support, with a brass frame for holding a sheet of blackened paper, exactly at a right angle to the support. The top of the inclined axis may be brought into slight contact with the blackened surface of the paper by lowering the brass frame on the stand by means of a micrometer-screw, so as to maintain the contact for some time.

The specimens of curves described by the apparatus show that without any disturbing force the top describes a circle.

If we put a circular disk excentrically on the axis of the apparatus, it still describes a circle, but also an ellipse revolving on its periphery, whose length of axis depends on the weight of the circular disk fastened to the axis. If the top marks for a longer time, instead of a circle a spiral line is described, with ellipses revolving on it.

Diagrams were exhibited, showing the same curves, but with heavier circular disks on the axis.

These experiments may be made also by putting on the top of the axis a globule of silvered glass, reflecting the light of the sun, or of a lamp, showing at a considerable distance the pretty designs of the nutation curves. It is very instructive to exhibit and explain the complicated phenomena of the luni-solar precession and nutation of the earth's axis by the same apparatus.

The combined action of the sun and moon's masses on the earth are represented by the small paper sheets put excentrically on the axis of the rotating brass disk of the apparatus.

The sun and moon's distances from the centre of the earth continually changing, produce the same effect as those circular disks put excentrically upon the axis of the apparatus, and produce an entirely similar motion of the axis of the earth, describing likewise a cone, or a circle on the top of the earth's axis; and by the changing action of the sun and moon at different distances from the earth, there is produced an additional small elliptical motion, quite similar to those represented in the diagrams exhibited. Similar but still larger elliptical motions are produced in the same manner by the combined and varying action of the sun and earth's masses on the moon, known in astronomy as the precession of the nodes of the moon, and as the nutation and evection of its axis.

Light.

Description of a Set of Lenses for the Accurate Correction of Visual Defect. By Philip Braham.

The lenses shown were plano-spherical and cylindrical. By using plano- instead of double spherical lenses, we are enabled to add or diminish the power of any given plano-lens to the greatest nicety; so that without multiplying the tools used by the lens-grinders, any graduation of focus can be obtained.

In correcting astigmatic defect, the cylindrical lenses being plano-, and the edges ground to the same exact diameter as the spherical, they fit together and act as one lens.

Description of a Paraboloidal Reflector for Lighthouses, consisting of silvered facets of ground-glass; and of a Differential Holophote. By Thomas Stevenson, *F.R.S.E., M.I.C.E.*

The superior advantages of the Dioptric as compared with the Catoptric systems

of illumination for lighthouses are generally admitted. There are, however, many cases, such as harbour-lights and ship-lights, where the expense of construction becomes a barrier to the employment of refracting apparatus.

In order to reduce the expense, it occurred to the author that it would be desirable to revive the old form of mirror, consisting of facets of ordinary silvered glass. Instead of making them small and with plane surfaces, the size may be much increased; and they may be bent or ground and polished on both faces to curves osculating the parabola, ellipse, or whatever form may be required. If the edges of these facets were fixed together by Canada balsam (a substance which has nearly the same index of refraction as plate-glass), the large loss of light which takes place at the edges of each facet in the old reflectors will be in great measure saved. There will not, as formerly, be any refraction of the rays in passing through the edges, and thus the whole will become practically *monodioptric*; or, in other words, will be optically nearly the same as if the paraboloid had been made of one whole sheet of glass, while the advantage due to accurately curved surfaces, instead of plane surfaces, will be secured. It would be a further improvement to select different points in the flame for the foci of the different facets, so as to secure the useful destination of more of the rays. Besides, by grinding each facet to different vertical and horizontal curves, the light may be condensed or diverged by means of a single agent; and the same result may be effected with different totally reflecting plates of flint or other glass cemented to lighthouse prisms with Canada balsam, so as to form composite prisms. When coloured lights are wanted, the facets would consist of glass tinted to the required hue, so as to render stained muffles or chimneys unnecessary. The economy of the proposed method of construction will render it peculiarly applicable to harbour-lights and ship-lights.

The author exhibited a paraboloidal reflector constructed on the method to which he referred. The facets were successfully constructed by Messrs. Chance, of Birmingham. The pieces of glass having been first bent upon a mould, were afterwards ground by rubbing-surfaces worked by machinery of the same kind as is employed for dioptric apparatus. The facets were afterwards silvered by the patent process of Messrs. Pratt and Co., of St. Helens, Lancashire, who inform the author that so long as the paint is not removed from the back of the silvering its reflecting power will remain unaltered.

Differential metallic Mirror and Holophote.—The same construction may also be adopted, as the author has already hinted, for producing a *differential holophote* which will, *by means of single optical agents, collect, with uniform density in azimuth, the whole sphere of diverging rays into any given cylindric sector.* For such a purpose each facet must, in the vertical plane where no divergence is wanted, be ground to a parabolic profile, while in the horizontal it must be of such hyperbolic, elliptic, or other curve as will give the required horizontal divergence without interference with the apparatus for the central cone of rays, which will be dealt with according to the requirements of the case, by means either of Fresnel's beehive fixed apparatus or of a differential lens—an instrument which the author has elsewhere described. In order to test the practicability of such an arrangement, a mirror was constructed of small glass facets, which were arranged optically on a surface of putty, and which answered the purpose as far as was possible with plain pieces of glass. The author sees therefore no great difficulty in making this new kind of mirror of separate facets of silvered glass of small size; but he found such difficulties in constructing one with a continuous surface that he consulted his friend Professor Tait, who kindly gave him his assistance in the solution of this difficult problem by supplying the general formula; and he has no doubt, now that the simpler form of facet has been so successfully constructed, a differential holophote will soon be made.

Notice of the Researches of the late Rev. William Vernon Harcourt, on the Conditions of Transparency in Glass, and the Connexion between the Chemical Constitution and Optical Properties of different Glasses. By Professor G. G. Stokes, *F.R.S.*

The preparation and optical properties of glasses of various compositions formed

for nearly forty years a favourite subject of study with the late Mr. Harcourt. Having commenced in 1834 some experiments on vitrifaction, with the object stated in the title of this notice, he was encouraged by a recommendation, which is printed in the 4th volume of the Transactions of the British Association, to pursue the subject further. A report on a gas-furnace, the construction of which formed a preliminary inquiry, in which was expended the pecuniary grant made by the Association for this research in 1836, is printed in the Report of the Association for 1844, but the results of the actual experiments on glass have never yet been published.

My own connexion with these researches commenced at the Meeting of the British Association at Cambridge in 1862, when Mr. Harcourt placed in my hands some prisms formed of the glasses which he had prepared, to enable me to determine their character as to fluorescence, which was of interest from the circumstance that the composition of the glasses was known. I was led indirectly to observe the fixed lines of the spectra formed by means of them; and as I used sunlight, which he had not found it convenient to employ, I was enabled to see further into the red and violet than he had done, which was favourable to a more accurate measure of the dispersive powers. This inquiry, being in furtherance of the original object of the experiments, seemed far more important than that as to fluorescence, and caused Mr. Harcourt to resume his experiments with the liveliest interest, an interest which he kept up to the last. Indeed it was only a few days before his death that his last experiment was made. To show the extent of the research, I may mention that as many as 166 masses of glass were formed and cut into prisms, each mass doubtless in many cases involving several preliminary experiments, besides disks and masses for other purposes. Perhaps I may be permitted here to refer to what I said to this Section on a former occasion* as to the advantage of working in concert. I may certainly say for myself, and I think it will not be deemed at all derogatory to the memory of my esteemed friend and fellow-labourer if I say of him, that I do not think that either of us working singly could have obtained the results we arrived at by working together.

It is well known how difficult it is, especially on a small scale, to prepare homogeneous glass. Of the first group of prisms, 28 in number, 10 only were sufficiently good to show a few of the principal dark lines of the solar spectrum; the rest had to be examined by the bright lines in artificial sources of light. These prisms appeared to have been cut at random by the optician from the mass of glass supplied to him. Theory and observation alike showed that striæ interfere comparatively little with an accurate determination of refractive indices when they lie in planes perpendicular to the edge of the prism. Accordingly the prisms used in the rest of the research were formed from the glass mass that came out of the crucible by cutting two planes, passing through the same horizontal line a little below the surface, and inclined $22\frac{1}{2}°$ right and left of the vertical, and by polishing the enclosed wedge of 45°. In the central portion of the mass the striæ have a tendency to arrange themselves in nearly vertical lines, from the operation of currents of convection; and by cutting in the manner described, the most favourable direction of the striæ is secured for a good part of the prism.

This attention to the direction of cutting, combined no doubt with increased experience in the manufacture of glass, was attended with such good results that now it was quite the exception for a prism not to show the more conspicuous dark lines.

On account of the inconvenience of working with silicates, arising from the difficulty of fusion and the pasty character of the fused glasses, Mr. Harcourt's experiments were chiefly carried on with phosphates, combined in many cases with fluorides, and sometimes with borates, tungstates, molybdates, or titanates. The glasses formed involved the elements potassium, sodium, lithium, barium, strontium, calcium, glucinum, magnesium, aluminium, manganese, zinc, cadmium, tin, lead, thallium, bismuth, antimony, arsenic, tungsten, molybdenum, titanium, vanadium, nickel, chromium, uranium, phosphorus, fluorine, boron, sulphur.

A very interesting subject of inquiry presented itself collaterally with the original object, namely, to inquire whether glasses could be found which would

* Report of the British Association for 1862, Trans. of Sect. p. 1.

achromatize each other so as to exhibit no secondary spectrum, or a single glass which would achromatize in that manner a combination of crown and flint.

This inquiry presented considerable difficulties. The dispersion of a medium is small compared with its refraction; and if the dispersive power be regarded as a small quantity of the first order, the irrationality between two media must be regarded as depending on small quantities of the second order. If striæ and imperfections of the kind present an obstacle to a very accurate determination of dispersive power, it will readily be understood that the errors of observation which they occasion go far to swallow up the small quantities on the observation of which the determination of irrationality depends. Accordingly, little success attended the attempts to draw conclusions as to irrationality from the direct observation of refractive indices; but by a particular method of compensation, in which the experimental prism was achromatized by a prism built up of slender prisms of crown and flint, I was enabled to draw trustworthy conclusions as to the character in this respect of those prisms which were sufficiently good to show a few of the principal dark lines of the solar spectrum.

Theoretically *any* three different kinds of glass may be made to form a combination achromatic as to secondary as well as primary colour, but practically the character of dispersion is usually connected with its amount, in such a manner that the determinant of the system of three simple equations which must be satisfied is very small, and the curvatures of the three lenses required to form an achromatic combination are very great.

For a long time little hope of a practical solution of the problem seemed to present itself, in consequence of the general prevalence of the approximate law referred to above. A prism containing molybdic acid was the first to give fair hopes of success. Mr. Harcourt warmly entered into this subject, and prosecuted his experiments with unwearied zeal. The earlier molybdic glasses prepared were many of them rather deeply coloured, and most of them of a perishable nature. At last, after numerous experiments, molybdic glasses were obtained pretty free from colour and permanent. Titanium had not yet been tried, and about this time a glass containing titanic acid was prepared and cut into a prism. Titanic acid proved to be equal or superior to molybdic in its power of extending the blue end of the spectrum more than corresponds to the dispersive power of the glass; while in every other respect (freedom from colour, permanence of the glass, greater abundance of the element) it had a decided advantage; and a great variety of titanic glasses were prepared, cut into prisms, and measured. One of these led to the suspicion that boracic acid had an opposite effect, to test which Mr. Harcourt formed some simple borates of lead, with varying proportions of boracic acid. These fully bore out the expectation; the terborate for instance, which in dispersive power nearly agrees with flint glass, agrees on the other hand, in the relative extension of the blue and red ends of the spectrum, with a combination of about one part, by volume, of flint glass with two of crown.

By combining a negative or concave lens of terborate of lead with positive lenses of crown and flint, or else a positive lens of titanic glass with negative lenses of crown and flint, or even with a negative of very low flint and a positive of crown, achromatic triple combinations free from secondary colour may be formed without encountering (at least in the case of the titanic glass) formidable curvatures; and by substituting at the same time a titanic glass for crown, and a borate of lead for flint, the curvatures may be a little further reduced.

There is no advantage in using three different kinds of glass rather than two to form a fully achromatic combination, except that the latter course might require the two kinds of glass to be made expressly, whereas with three we may employ for two the crown and flint of commerce. Enough titanium might, however, be introduced into a glass to render it capable of being perfectly achromatized by Chance's "light flint."

In a triple objective the middle lens may be made to fit both the others, and be cemented. Terborate of lead, which is somewhat liable to tarnish, might thus be protected by being placed in the middle. Even if two kinds only of glass are used, it is desirable to divide the convex lens into two, for the sake of diminishing the curvatures. On calculating the curvatures so as to destroy spherical as

well as chromatic aberration, and at the same time to make the adjacent surfaces fit, very suitable forms were obtained with the data furnished by Mr. Harcourt's glasses.

After encountering great difficulties from striæ, Mr. Harcourt at last succeeded in preparing disks of terborate of lead and of a titanic glass which are fairly homogeneous, and with which it is intended to attempt the construction of an actual objective which shall give images free from secondary colour, or nearly so.

This notice has extended to a greater length than I had intended, but it still gives only a meagre account of a research extending over so many years. It is my intention to draw up a full account for presentation to the scientific world in some other form. I have already said that the grant made to Mr. Harcourt for these researches in 1836 has long since been expended, as was stated in his Report of 1844; but it was his wish, in recognition of that grant, that the first mention of the results he obtained should be made to the British Association; and I doubt not that the members will receive with satisfaction this mark of consideration, which they will connect with the memory of one to whom the Association as a body is so deeply indebted.

On one Cause of Transparency. By G. Johnstone Stoney, *M.A.*, *F.R.S.*

The motion of the æther which constitutes light is known to be subject to four restrictions:—First, it is periodic; secondly, it is transversal; thirdly, it is (at all events temporarily) polarized; and, fourthly, its periodic time lies between the limits which correspond to the extent of the visible spectrum. By temporary polarization is meant the persistence of the same kind of wave over a long series of waves before waves of another kind succeed, that persistence which the phenomena of diffraction have made known to us*.

And the many respects in which radiant heat and light have been found to be identical enable us to say that the first three of the foregoing restrictions apply to radiant heat. We also know (see 'Philosophical Magazine' for April and for July 1871) that the lines in the spectra of gases arise from periodic motions in the molecules of the gas, each such motion giving rise to one or more lines corresponding to terms of an harmonic series. And we know that under certain conditions these lines dilate and run into one another, so as in many cases to produce regions of continuous absorption. All these phenomena may safely be attributed to periodic motions in the molecules of the gas, the dilatation of the lines being due to perturbations which affect the periodic times. After the periodic time has been disturbed (probably on the occasion of the collisions between molecules) it seems to settle down gradually towards its normal amount, thus imparting breadth to the corresponding spectral lines.

The question now naturally presents itself—What results from motions in the molecules which are not periodic, or which are in any other way unfitted to produce radiant heat? And here the phenomena of acoustics come to our aid. When a bell is struck, more or less regularly, periodic motions are both produced. The more regularly periodic motions produce the tone of the bell which is heard at a distance, while the less regular motions, though they are often very intense, produce a clang heard only in the vicinity of the bell; in other words, the energy is expended in the neighbourhood of the bell. Similarly, if the molecules of a body are engaged in irregular motions, such motions, though they may occasion a violent agitation of the others, are mechanically incapable of producing such an undulation as constitutes radiant heat. The disturbance is necessarily local; in other words, as much energy is restored by the moving æther to the molecules as is imparted by the motion of the molecules to the æther. This absence of radiation is one of the properties of a transparent body; and the other thermal (or optical) properties of transparent bodies may be presumed to depend also on these partially irregular motions. Thus Fizeau has proved by experiment that a flow of water of about

* Rays of common light have been found to interfere, of which one was retarded 15 millims., or about 30,000 wave-lengths, behind the other, showing what a long series of nearly similar waves usually succeed one another in unpolarized light before waves of another type come in.

seven metres per second produced a very sensible effect on the velocity with which light was propagated in the direction of the motion; in other words, when the molecular motions had a preponderance in one direction, this was found to alter the refractive index in that direction. This shows that the molecular motions do affect the refractive index; and it is perhaps not too much to presume that the phenomena of the irrationality of the spectra produced by prisms of different materials of double refraction and polarization in crystals of other than the cubical system, and of circular polarization in solids and liquids, will be found to result from modifications of the irregular motions either of or within the molecules. Other facts appear to confirm this presumption: where from the form of a crystal we have reason to suppose that the irregular molecular motions are not symmetrically distributed in different directions, there we uniformly find the phenomena of double refraction; and in those solids where they are symmetrically disposed the refraction becomes double if they are exposed to strain, *i.e.* as soon as an unsymmetrical distribution of the molecular motions is artificially induced.

On the whole we appear justified in drawing the probable inference that all the phenomena of transparency are intimately associated with the molecular motions which want that kind of regularity which would fit them to be the source of luminous undulations. What is certain is, first, that certain periodic molecular motions do produce the phenomena of opacity in gases; and secondly, that irregular molecular motions are incapable of producing the effect of opacity, since they cannot radiate. By irregular motions, where the phrase occurs in this communication, are to be understood motions which are not approximately periodic, or which from any other cause cannot set up in the æther such an undulation as that which constitutes radiant heat.

On the advantage of referring the positions of Lines in the Spectrum to a Scale of Wave-numbers. By G. JOHNSTONE STONEY, *M.A., F.R.S.*

At the last Meeting of the British Association Mr. Stoney made a communication, from which it seemed to appear that each periodic motion in the molecules of a gas will in general (*i.e.* unless the motion be a simple pendulous one, or else mechanically small) give rise to *several* lines in the spectrum of the gas, and that the lines which thus result from one motion have periods that are harmonics of the periodic time of the parent motion. Since that time he has been engaged, in conjunction with Dr. Emerson Reynolds, of Dublin, in testing this theory; and in this inquiry it has been found convenient to refer the positions of all lines in the spectrum to a scale of reciprocals of the wave-lengths. This scale has the great convenience, for the purposes of the investigation, that a system of lines with periodic times that are harmonics of one periodic time are equidistant upon it; and it has the further convenience, which recommends it for general use, that it resembles the spectrum as seen in the spectroscope much more closely than the scale of direct wave-lengths used by Ångström in his classic map.

The position marked 2000 upon this scale occurs about the middle of the spectrum, and corresponds to Ångström's wave-length 5000. The numbers which Ångström uses are tenth-metres, *i.e.* the lengths obtained by dividing the metre into 10^{10} parts; and from this it follows that each number on the new scale signifies the number of light-waves in a millimetre: thus 2000 upon a map drawn to this scale marks the position of the ray whose wave-length is $\frac{1}{2000}$ of a millimetre. The new scale may therefore be appropriately called a scale of wave-numbers. If, then, k be the wave-number of a fundamental motion in the æther, its wave-length will be $\frac{1}{k}$th of a millimetre, and its harmonics will have the wave-lengths $\frac{1}{2k}$, $\frac{1}{3k}$, &c.; in other words, they occupy the positions $2k$, $3k$, &c. upon the new map. Hence it is easy to see that a system of lines which are equally spaced along the map at intervals of k divisions are harmonics of a fundamental motion whose wave-number is k, whose wave-length is $\frac{1}{k}$th of a millimetre, and

whose periodic time is $\frac{\tau}{k}$; where τ is the periodic time of an undulation in the æther consisting of waves one millimetre long. If we use Foucault's determination of the velocity of light, viz. 298,000,000 metres per second, the value of this constant is

$$\tau = 3\cdot3557 \text{ twelfth-seconds,}$$

meaning by a twelfth-second a second of time divided by 10^{12}, which, in other words, is the millionth part of the millionth of a second of time.

Thus the proposed numbers give the same information as a list of direct wave-lengths, and in a more commodious form for theoretical purposes; while at the same time the map of the spectrum drawn to this scale is to be preferred for use in the laboratory, because it represents the spectrum formed by a prism with comparatively little distortion. This will be apparent from the following Table of the wave-numbers of the principal lines of the solar spectrum:—

A	1315·1	E_1	1896·7	F	2057·3
B	1456·2	E_2	98·0	G	2321·7
C	1523·9	b_1	1929·3	*h*	2438·3
D_1	1696·3	b_2	33·4	H_1	2520·1
D_2	98·0	b_4	35·4	H_2	42·6

On the Wave-lengths of the Spectra of the Hydrocarbons. *By* Professor William Swan, *LL.D., F.R.S.E.*

The author stated that in 1856 he had communicated to the Royal Society of Edinburgh a paper, published in vol. xxi. of their Transactions, entitled "On the Prismatic Spectra of the Flames of Compounds of Carbon and Hydrogen." In his observations on these substances he made use of an arrangement (employed by him still earlier in 1847) identical with that which, since the publication of Kirchhoff and Bunsen's researches in Spectrum-analysis, is familiarly known as a "Spectroscope," namely, an observing telescope, a prism, and a collimator, receiving the light to be examined through a narrow slit at its principal focus.

The observations published in 1856 consist of carefully observed minimum deviations of fourteen dark lines of the sun spectrum, and of twelve bright lines of the hydrocarbon spectra, which bright lines were found to be identical in fifteen different hydrocarbons examined. No absolute coincidences between the lines in the solar and terrestrial spectra were observed, except that, long before discovered by Fraunhofer, between the double sun-line D and the double yellow line of ordinary flames, *now*, wherever it may be seen, referred to sodium.

The yellow line was generally present in the hydrocarbon spectra; but, from a careful quantitative experiment, it was ascertained that the 2,500,000th part of a troy grain of sodium rendered its presence in a flame sensible: and the conclusion was then distinctly stated, it is believed for the first time, that whenever or wherever the double yellow line appears it is due to the presence of minute traces of sodium.

In this state the observations of 1856 had remained until lately, when the author was requested by his friend Professor Piazzi Smyth to compute the wave-lengths of some of the hydrocarbon lines. As no exact coincidence existed between these and the lines of the solar spectrum, it was necessary to have recourse to some process of interpolation; and that which suggested itself to the author was founded upon Lagrange's well-known Interpolation theorem. In order to verify as far as possible the results, the computation of the wave-lengths of the hydrocarbon lines was repeated by interpolating between different groups of sun lines; and the discrepancies between the numbers so obtained in no case extended beyond the place of units in Ångström's scale of wave-lengths, where unity expresses the ten millionth part of a millimetre. The subject was brought before the Association in order

to elicit an opinion whether the results likely to be obtained would be of sufficient importance to warrant a more elaborate discussion of the entire series of observations with a view to future publication.

Poste Photographique. By the Abbé Moigno.

An Account of a New Photographic Dry Process. By R. Sutton.

Heat.

Description of Experiments made in the Physical Laboratory of the University of Glasgow to determine the Surface Conductivity for Heat of a Copper Ball. By Donald M'Farlane.

The experiments described in this paper were made under the direction of Sir W. Thomson during the summers of 1865 and 1871. A hot copper ball, having a thermoelectric junction at its centre, was suspended in the interior of a closed space kept at a constant temperature of about 16° Cent., the other junction was kept at the temperature of the envelope, the circuit was completed through a mirror galvanometer, and the deflections noted at intervals of one minute as the ball gradually cooled.

The method of reducing the observations was explained at length. The difference of the Napierian logarithms of the differences of temperatures of the junctions, indicated by the deflections, divided by the intervals of time, gives the rate of cooling; and this, multiplied by a factor depending on the capacity for heat of the ball and on the extent of its surface, gives the quantity of heat emitted in gramme water units in the unit of time per square centimetre, per 1° of difference of temperatures. Formulæ were given which express the results of the experiments very closely, and a table calculated by them exhibits the rates of emission for every 5° of difference throughout the range.

The first and second series had a range of from 5° to 25° only, which was too small to give decided results; but the third and fourth series, made with a polished copper surface and a blackened surface respectively, gave variations in the emissive power from ·000178 at 5° diff. of temperature to ·000226 at 60° diff. for the polished surface, and from ·000252 at 5° diff. to ·000328 at 60° diff. for the blackened surface; and the emissive powers of the two surfaces exhibit throughout a nearly constant ratio to each other of about ·694.

On a Respirator for Use in Extinction of Fires. By William Ladd, *F.R.A.S.*

This instrument combines the advantages of the charcoal and the cotton-wool respirators. The respirator is intended to be fitted on the heads of firemen, and it will enable a fireman to enter into the midst of any smoke, however dense. There is sufficient protection for the eyes, by means of glasses. The results of an experiment with the respirator have been stated by Prof. Tyndall. In a small cellar-like chamber, furnaces containing resinous pine-wood were placed, and the wood being lighted, a dense smoke was generated. In this room, Prof. Tyndall and his assistant, using these respirators, remained for more than half an hour, when the smoke was so dense and pungent that a single inhalation through the unprotected mouth and nostrils would have been perfectly unendurable. The instrument has been tested by Capt. Shaw, chief officer of the Metropolitan Fire Brigade, who has taken very great interest in perfecting it, by attaching to it suitable hoods.

On the Temperature-equilibrium of an Enclosure in which there is a Body in Visible Motion. *By* Prof. Balfour Stewart, *F.R.S.*

It is now several years since Professor Tait and the author of this paper came jointly to entertain the belief that there is some transmutation of energy, the exact nature of which is unknown, when large bodies approach or recede from one another. It is desirable to vindicate an idea of this nature, both from the theoretical and the practical point of view—that is to say, we ought, if possible, to exhibit it as a probable deduction from those laws of nature with which we are already acquainted; and, on the other hand, it ought to be supported by observations and experiments of a new kind. In our case the experiments and observations have been of a difficult nature, and are yet in progress; it is therefore premature to bring them before the notice of the Association. A theoretical vindication of the idea has been obtained by Professor Tait, and more recently one has occurred to the author of these remarks, which he now ventures to bring forward. Men of science are now sufficiently well acquainted with Prevost's theory of exchanges, and its recent extension. We know that in an enclosure, the walls of which are kept at a constant temperature, every substance will ultimately attain the very same temperature as these walls, and we know also that this temperature-equilibrium can only be brought about by the absorption of every particle being exactly equal to its radiation, an equality which must separately hold for every individual kind of heat which the enclosure radiates. This theoretical conclusion is supported by numerous experiments, and one of its most important applications has been the analysis of the heavenly bodies by means of the spectroscope. Let us now suppose that in such an enclosure we have a body in visible motion, its temperature, however, being precisely the same as that of the walls of the enclosure. Had the body been at rest, we know from the theory of exchanges that there would have been a perfect equilibrium of temperature between the enclosure and the body; but there is reason to believe that this state of temperature-equilibrium is broken by the motion of the body. For we know both from theory and experiment that if a body, such for instance as a star, be either rapidly approaching the eye of an observer or receding from it, the rays from the body which strike the eye will no longer be precisely the same as would have struck it had the body been at the same temperature and at rest—just as the whistle of a railway engine rapidly approaching an observer will have to him a different note from that which it would have had if the engine had been at rest. The body at motion in the enclosure is not therefore giving the enclosure those precise rays which it would have given it had it been at the same temperature and at rest; on the other hand, the rays which are leaving the enclosure are unaltered. The enclosure is therefore receiving one set of rays and giving out another, the consequence of which will be a want of temperature-equilibrium in the enclosure, in other words, all the various particles of the enclosure will not be of the same temperature. Now, what is the consequence of this? The consequence will be that we can use these particles of different temperature so as to transmute part of their heat into the energy of visible motion, just as we do in a steam-engine; and if it is allowable to suppose that during this process the moving body has retained all its energy of motion, the result will be an increase of the amount of visible energy within the enclosure, all the particles of which were originally of the same temperature. But Sir W. Thomson has shown us that this is impossible; in other words, we cannot imagine an increase of the visible energy of such an enclosure unless we acknowledge the possibility of a perpetual motion. It is not, therefore, allowable to suppose that in such an enclosure the moving body continues to retain all its energy of motion, and consequently such a body will have its energy of motion gradually stopped. Evidently in this argument the use of the enclosure has been to enable us to deduce our proof from the known laws of heat and energy, and we may alter the shape of the body without affecting the result; in other words, we should expect some loss of visible energy in the case of cosmical bodies approaching or receding from one another.

On a new Steam-gauge. *By* Prof. Ch. V. Zenger.

This gauge is intended to avoid the defects of common air-gauges, which have

hitherto prevented the employment of the air-manometer, and at the same time to be more accurate and unalterable in its working than the spring gauges now commonly used for steam-boilers. In the first place, it is a great defect in the common air-gauge that the divisions on the manometric tube diminish rapidly at high pressures, and consequently the reading becomes less and less accurate the higher the pressure. The new steam-gauge, on the contrary, possesses the same degree of accuracy at all pressures, and even enables us to make the accuracy of reading greater at higher pressures.

Another serious defect of the air-manometer is the liability to rupture of the narrow column of mercury when the steam is suddenly shut off or turned on. This is entirely avoided in the present instrument by the use of two closed vessels communicating with each other only by very narrow capillary tubes. Finally, the small column of mercury enclosed in the glass tube of common air-manometers is subject to capillary depression, and to the disturbing effects of heat upon the air-bulb and upon the mercury.

In the instrument now to be described it is sought to avoid these defects by not using capillary tubes for the manometer, and by disposing the air and mercury in such a way as to make the effect of heat insensible.

The air-tube of the manometer consists of a series of tubes of equal length, but different diameters, joined together by means of a blowpipe, and ending at the top in a glass bulb. The lower end is connected by an air-tight screw, joined with the first of two iron vessels containing each mercury or some other liquid, and communicating only by a very narrow capillary tube or channel.

The manometric tube is sealed at the bottom, but there are two fine capillary openings through the side at points below the surface of the mercury or other liquid contained in the two iron vessels. Hence the communication of pressure from the steam or other compressed gas, whose pressure is to be measured, and which presses directly upon the surface of the liquid in the second iron vessel, can only take place through a system of two capillary channels; and the resistance which these channels oppose to the motion of the mercury, by which they are filled, makes it impossible for sudden changes to occur in the height of the manometric column, and thus entirely prevents the division of the column or the entry of steam or gas into the manometer.

The capacities of the tubes and of the globe, which compose the manometric tubes, are so adjusted that they decrease in the same ratio in which the pressure increases, which is evidently what is required by Mariotte's law in order that an increase of pressure of one atmosphere may cause the first tube to be filled by the enclosing liquid, and that a further increase of pressure of the same amount may cause the second tube to be filled, and so on, each equal increment of pressure causing the same rise of the liquid in the manometric tube. This adjustment of the capacities is effected as follows:—Let the capacity of a manometer, to be divided so as to show pressures up to, say, four atmospheres, be called unity, and let v_1, v_2, v_3, and v_4 be the capacities of the first, second, and third tube and of the terminal globe respectively, then we have—

$$v_1+v_2+v_3+v_4=1 \text{ for one atmosphere.}$$
$$v_2+v_3+v_4=\tfrac{1}{2} \text{ for two atmospheres.}$$
$$v_3+v_4=\tfrac{1}{3} \text{ for three} \quad ,,$$
$$v_4=\tfrac{1}{4} \text{ for four} \quad ,,$$

This gives for the capacities of the tubes and their radii:—

$$v_1=\tfrac{1}{2}=\frac{1}{1.2}, \qquad r_1=\frac{1}{\sqrt{2\pi h}},$$
$$v_2=\tfrac{1}{6}=\frac{1}{2.3}, \qquad r_2=\frac{1}{\sqrt{6\pi h}},$$
$$v_3=\tfrac{1}{12}=\frac{1}{3.4}, \qquad r_3=\frac{1}{\sqrt{12\pi h}},$$
$$v_4=\tfrac{1}{4}, \qquad =\frac{1}{\sqrt[3]{\frac{3}{16}\pi}},$$

where h is the length of each tube. To prevent accidental breakage of the manometer, it is fastened to the graduated brass plate, and with it screwed to a glass cover $\frac{1}{4}$ of an inch thick, capable of supporting a pressure of 20 atmospheres.

Electricity and Magnetism.

On the Influence of Clean and Unclean Surfaces in Voltaic Action. *By* Thomas Bloxam, *Lecturer on Chemistry, Cheltenham College.*

1. Gas was evolved by the contact of zinc and platinum surfaces, then an equal amount from the same surfaces when the platinum had been cleaned by hot oil of vitriol; the time was exactly half when the clean surfaces were used; contact of the surfaces with the fingers or dipping them in solutions of various substances was found to retard the evolution in a very marked degree.

2. Heating the platinum in a measure cleaned it, but not so satisfactorily as hot oil of vitriol. Copper and other metals behaved similarly to platinum.

3. Platinized silver, from its method of manufacture, appeared to be already clean, no advantage being obtained by chemically cleaning it.

4. Mechanically roughened surfaces of platinum exhibited a decided advantage over smooth ones.

5. The cell of a Smee's battery, examined by a galvanometer, gave vastly better results when the negative plate had been chemically cleaned.

6. Voltameters, the plates of which had been chemically cleaned, exhibited a marked superiority over those not so cleaned; thus it appears that in all voltaic action the results are superior where the surfaces of the negative metals, electrodes, &c. have been chemically cleaned, and that mere contact with the finger is sufficient to modify the evolution of gases from the surface.

On a new Form of Constant Galvanic Battery. *By* Latimer Clark, *C.E.* (*Extracted from a Letter to* Sir William Thomson.)

I have spoken to you several times about a form of battery which can be set up under such conditions as to ensure uniformity of tension within limits of about ·05 or ·06 per cent., and that without any special precautions as to the purity of the materials employed. I have not yet been able to make the necessary experiments for determining its value in absolute units, though I hope shortly to have made an independent determination. I have, however, set up about 200 of the elements in question, and have measured them on about 30 different days; and from the mean of these experiments, taking the Daniell at 1·079 volts, I make this element to be 1·403 volts. In obtaining this result I have had to make careful measurements of electromotive force of more than 1000 different elements, comprising some 40 or 50 different kinds; in fact I have been working at it for six years.

The element in question varies about ·07 per cent. for each degree Centigrade, getting weaker with increased temperature: the temperature at which our comparison with the Daniell's cell is made is 18° Centigrade.

The element consists of a cylinder of pure zinc resting on a paste of protosulphate of mercury and saturated solution of sulphate of zinc, previously boiled to expel the air, the other electrode being metallic mercury, connexion being made with the latter by a platinum wire. It is desirable that the materials should be pure; but if commercial materials be employed the error does not exceed ·06 per cent. at first, and after three or four hours the value becomes sensibly the same as with pure materials.

The precautions necessary are that the protosulphate of mercury should be free from persulphate, and that the solution of persulphate of zinc should be supersaturated. The elements do not vary sensibly for two or three months, say ·05 per cent.

It is essential that the element *should not be worked through small interpolar*

resistance; but the measurement should be made by the use of a condenser, or, infinitely better, by my "Potentiometer," which, with a Thomson's reflecting galvanometer, readily measures to the millionth part of a Daniell's cell, or very much less if required.

Notice of and Observations with a New Dip-circle. *By* J. P. Joule, *LL.D., F.R.S., &c.*

The method of suspension of the needle, which formed the principal feature of the new instrument, was explained. The increased facilities of observation had enabled the author to trace the diurnal variation of inclination with greater accuracy than he believed had hitherto been done. At Manchester, about the summer solstice, the greatest inclination was found to occur at $21^h\ 40^m$ local time, and the range extended to $5'$. The simultaneous variation of horizontal intensity was such as to indicate that the total intensity was very nearly a constant quantity.

On Thermo-electricity. *By* Professor Tait.

It results from Thomson's investigations, founded on the beautiful discoveries of Peltier and Cumming, that the graphic representation of the electromotive force of a thermo-electric circuit, in terms of temperatures as abscissæ, is a curve symmetrical about a vertical axis. This I have found to be, within the limits of experimental error, a parabola in each one of a very extensive series of investigations which I have made with wires of every metal I could procure. To verify this result with great exactness, and at the same time to extend the trial to temperatures beyond the range of a mercurial thermometer, I made a graphic representation, in which the abscissæ were the successive indications of one circuit, the ordinates those of another, the temperatures being the same in both. It is easy to see that if the separate circuits give parabolas (as above) in terms of temperature, this process also should lead to a parabola, the axis, however, being no longer vertical. This severe test was well borne, even to temperatures approaching a dull red heat. Unfortunately, it is difficult to procure wires of the more infusible metals, with the exception of platinum and palladium, so that I have not yet been able to push this test to very high temperatures. I hope, however, with the kind assistance of M. H. Sainte-Claire Deville, to have wires of nickel and cobalt, with which to test the parabolic law through a very wide range.

Parabolas being similar figures, it is easy to adjust the resistances in any two circuits so as to make their parabolas (in terms of temperature) *equal*. When this is done, if the neutral points be different, it is obvious that by making them act in opposite directions on a differential galvanometer we shall have deflections *directly proportional* to the temperature-differences of the junctions.

It is a curious result of this investigation, that, supposing the parabolic law to be true, the Peltier effect is also expressed by a parabolic function of temperature, vanishing at absolute zero.

I was led to this inquiry by a hypothetical application of the Dissipation of Energy to what Thomson calls the electric convection of heat, and my result is verified (within the range of my experiments), that the specific heat of electricity is directly proportional to the absolute temperature. It is scarcely necessary to point out that the above results appear to promise a very simple solution of the problem of measuring high temperatures, such as those of furnaces, the melting-points of rocks, &c.

On a Method of Testing Submerged Electric Cables. *By* C. F. Varley.

On a New Key for the Morse Printing Telegraph. *By* Ch. V. Zenger, *Professor of Natural Philosophy at the Polytechnic School in Prague.*

I had devised in 1868 a new automatic key to work the Morse telegraph. It produced three marks, viz. a point, a short line, and a long line. It con-

sisted of three levers; by pressing them down steel springs moved along a very short, or along longer sheets of conducting material, and formed thus three signs of different lengths. Yet there was a certain time required to work the three keys; to obviate it, and to put the telegraphist entirely at his ease as to the speed attainable for him, and to obtain in such a manner the highest speed possible, I constructed the key in another manner.

A clockwork arrangement moves a small wooden cylinder, whose steel axis is attached to it by a handle, and rotates with great velocity, the rate of velocity being accurately indicated by sounding a small bell as often in a second as the cylinder will revolve in the same time.

The wooden cylinder bears three thin circular disks of brass attached to the steel axis of the cylinder; these disks are differently cut out, in such a manner that the first is a full circle of 360°, the second a sector of nearly 120°, the rest of the circle being covered with an insulating material, viz. wood or india-rubber, to prevent metallic contact.

The third disk is only a segment of 10°, the rest being cut out and covered with the insulating material.

Three levers, put in front of the three disks, bear on their ends platinum wires or plates that touch the disks during one revolution of the cylinder when pressed down.

From the levers a conducting-plate, uniting them, leads to the printing apparatus, and the levers are reduced to their former position by strong steel springs, so that they regain rapidly their positions after the pressure of the finger has ceased. Whatever be the velocity of the paper and the rollers, and the clockwork moving it, the relative length of the sizes and their distances remain unalterably the same.

In the model presented to the General Post Office, the motion endures for 15 minutes, and, being only a model, it is worked by a spring, and it has no rollers for the paper.

In the working apparatus for telegraphic use, the rollers and whole printing apparatus are attached to the key, and the same clockwork moves both the rollers and the rotating cylinder, forming thus only one apparatus together. From that contrivance we obtain:—

1. A quite equal distance between the signs, as in printing.
2. By putting the fans of the clockwork in differently inclined positions, the velocity may be carried to as great an extent as a clever clerk can manage it.
3. By using three signs instead of two, the signs for letters, figures, and phrases are reduced about one-third, and as much of time and space is spared.

Meteorology.

On the Importance of the Azores as a Meteorological Station. *By* Dr. Buys Ballot.

In this paper the author classed his remarks under three heads:—(1) as to the importance of the station; (2) as to the present condition of the question of its establishment; (3) what remains to be done. He showed that, although we have very copious results of observations made by vessels crossing the various oceans in all directions, there is great deficiency of actual observations at *fixed* points. After pointing out the very important position occupied by the Azores, as illustrated by the researches of Mr. Buchan and Prof. Mohn with reference to the normal tracks of European storms, and also in their lying so completely in the path of merchant vessels, Dr. Ballot explained that about five years ago he submitted to the British Admiralty a proposal for establishing a chain of barometric stations in the S. and W. of the British Isles, and at the Azores, and obtaining meteorological reports from thence. In April 1866 he applied to the Portuguese Government and to various learned meteorologists; and the Director of the Lisbon Observatory has been to Holland to consult Dr. Ballot on the subject.

A concession has been granted for the laying of a cable to the Azores; a learned

Portuguese has undertaken to provide the instruments and instruct the observer. The only expense involved is the charge for the transmission of the telegraph-messages: it would be most unfair that a country like Portugal should bear *all* the cost (about £350 per annum for one message daily); and Dr. Ballot thinks that it should be raised jointly and proportionally by the European Maritime States, all of whom would largely benefit by the adoption of the proposal.

Mean Temperature of Arbroath. Latitude 56° 33′ 35″ *North, Longitude* 2° 35′ 30″ *W. of Greenwich. By* ALEXANDER BROWN, *LL.D.*

Months.	Mean temperature.				Mean Temperature of different Periods.				Differences between 4 years and		
	1	2	3	4	5	6	7	8			
	1867.	1868.	1869.	1870.	4 years.	13 years.	22 years.	26 years.	13 years.	22 years.	26 years.
	°	°	°	°	°	°	°	°	°	°	°
January	33·0	41·3	41·0	36·4	37·9	37·5	36·4	36·6	−0·4	−1·5	−1·3
February ...	42·1	42·3	42·7	36·7	40·9	38·4	37·0	37·6	−2·5	−3·9	−3·3
March	37·8	43·6	38·9	40·8	40·2	39·9	39·7	39·7	−0·3	−0·5	−0·5
April	47·1	47·4	47·7	48·0	47·5	48·0	43·8	44·3	+0·5	−3·7	−3·2
May	47·4	52·6	46·8	52·3	49·7	49·7	49·2	49·2	0·0	−0·5	−0·5
June	55·9	57·1	54·6	57·7	56·3	55·9	55·3	55·4	−0·4	−1·0	−0·9
July	54·0	60·6	61·6	61·0	59·3	58·3	58·2	58·3	−1·0	−1·1	−1·0
August	58·6	59·5	57·8	58·4	58·6	57·6	57·2	57·4	−1·0	−1·4	−1·2
September ...	55·7	54·6	55·4	55·1	55·2	54·3	53·4	53·6	−0·9	−1·8	−1·6
October	47·7	45·5	48·1	47·7	47·2	47·3	46·8	46·9	+0·1	−0·4	−0·3
November ...	42·5	41·4	41·6	40·0	41·4	40·8	40·4	40·5	−0·6	−1·0	−0·9
December ...	38·8	41·2	35·2	35·3	37·6	38·8	37·9	37·9	+1·2	+0·3	+0·3
Means......	46·7	48·9	47·6	47·4	47·6	47·0	46·3	46·4	−0·6	−1·3	−1·2

The author constructed from his meteorological journals the foregoing Table for the purpose of showing the Mean Annual Temperature at Arbroath, in the county of Forfar, on the east coast of Scotland. In the Table, columns nos. 1, 2, 3, and 4 give the monthly mean temperature, and also the annual mean temperature, of each of the years 1867, 1868, 1869, and 1870. The warmest of these four years was 1868, and the coldest the year immediately preceding, namely 1867. The mean temperature of 1868, as shown by the Table, was 48°·9, and that of 1867 46°·7, the difference between the warmest and coldest year of the four being 2°·2. Column 5 is the mean of the monthly and annual temperature of the four years already mentioned; column 6 is the mean of 13 years, from 1857 to 1869 inclusive; column 7 is the mean of 22 years, from 1845 to 1866 inclusive; and column 8 is the mean of 26 years, from 1845 to 1870 inclusive. The annual mean temperature of the 4-year period is 47°·6, of the 13-year period 47°·0, of the 22-year period 46°·3, and of the 26-year period 46°·4. It will be observed that the annual means of the two long periods differ by only one tenth of a degree, and are therefore a near approximation to the mean temperature of the locality.

The thermometers used are the Minimum thermometer of Rutherford and the Maximum thermometer of Negretti and Zambra, which have been tested by the Standard instruments of the Scottish Meteorological Society. They are attached to a wooden frame fixed to a window-sill having a northern exposure. Very great care is taken to protect the instruments from the effects of radiation and other causes. The thermometers are placed 11 feet from the ground and 70 feet above the level of the sea, and distant therefrom 783 yards in a direct line.

On the Thermo-Dynamics of the General Oceanic Circulation. *By* WILLIAM B. CARPENTER, *LL.D., M.D., F.R.S.*

The object of this communication was to bring under the consideration of Physicists the fact, ascertained by recent Deep-Sea explorations, of the general prevalence of a temperature not much above 32° F. over the bottom of the great Ocean-beds, at depths greater than 2000 fathoms. As it has been proved by Temperature-soundings made in the Mediterranean that the temperature of its bottom at like depths is about 54° F., it is obvious that depth, *per se*, has no relation to the phenomenon. And the explanation of it propounded by the author is, (1) that a body of Polar water flows over the deepest portions of the Oceanic basins which communicate with the Arctic and Antarctic areas; (2) that this flow has its origin in the action of Polar cold on the water subjected to its influence, whereby *a descending movement* is imparted to the whole mass; besides which, the Polar column, in virtue of its greater density, will have a greater downward pressure than the Equatorial column at the same level; (3) that this bottom outflow will produce an indraught of the more superficial stratum of Ocean water towards the Polar areas; (4) and that a *vertical circulation* will thus be maintained by difference of Temperature alone, carrying the lower cold stratum of Ocean water from the Polar towards the Equatorial area, and the upper warm stratum from the Equatorial towards the Polar.

A different explanation of the facts, however, has been offered by those who regard the *Horizontal Circulation*, of which the Trade-winds are the *primum mobile*, as the sole cause of the amelioration of the temperature of the Arctic basin, by an afflux of warm water; for it has been urged that the driving off of the superficial stratum of Equatorial water in the Gulf-stream must produce a partial void in that area, which will be filled by a deep indraught of Polar water.—This appears to the author extremely improbable, on general physical grounds. A horizontal movement of surface-water in the open Ocean would not draw up water from below, so long as a *lateral* influx can keep up its level; so that any such horizontal Wind-current must have another *horizontal* movement to complete the circulation. Such a horizontal complement is obvious in the case of the Gulf-stream, of which one portion turns round the Azores to re-enter the Equatorial current, thus completing the shorter circulation; whilst the other portion, which flows onwards in a N.E. direction, has as *its* complement the various cold surface-currents which are known to set southwards, and of which it is shown by recent observations that one tends towards the coast of Mogador, sending an offset through the Strait of Gibraltar.

Further, it was argued by the author that the temperature-phenomena obtained in recent explorations indicate that a N.E. movement of the upper stratum of Oceanic water extends between the coast of Spain and the Faroe Islands to a depth of 500 or 600 fathoms, and that while this cannot be attributed to any propulsive action derived from the Gulf-stream (the thinned out edge of which is less than 50 fathoms in depth), it is exactly such a flow as would be anticipated on the hypothesis of a vertical circulation sustained by opposition of Temperature.

On the Mathematical Theory of Atmospheric Tides. *By the* Rev. Professor CHALLIS, *M.A., LL.D., F.R.S.*

The purpose of the author in this communication was to point out a process of analytical reasoning by which the solution of the problem of atmospheric tides might be strictly derived from the general equations of hydrodynamics. For the sake of simplicity, the surface on which the atmosphere rests was supposed to be exactly spherical, the earth was conceived to have no motion of rotation, and the tidal motion to be produced by the moon revolving westward in the plane of the earth's equator, at her mean distance (R), and with the mean relative angular velocity (μ). Also it was assumed that the relation between the pressure (p) and density (ρ) is at all times and at all points of the atmosphere $p=a^2\rho$, the effects of variation of temperature not being taken into account.

As tidal motion is oscillatory, and the oscillations are so small that it is un-

necessary to proceed beyond the first order of small quantities, the following equations, expressed in the usual notation, were adopted as being sufficiently general and approximate for the purpose :—

$$\frac{d^2\phi}{a^2dt^2} = \frac{d^2\phi}{dx^2} + \frac{d^2\phi}{dy^2} + \frac{d^2\phi}{dz^2} \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\frac{a^2(d\rho)}{\rho} = \mathrm{X}dx + \mathrm{Y}dy + \mathrm{Z}dz - d.\frac{d\phi}{dt}. \ldots\ldots\ldots\ldots \quad (2)$$

The proposed method of solving the problem of tides requires, first, that equation (1) should be satisfied by a particular integral of assigned form; and then that the arbitrary quantities contained in this integral, together with that arising from the integration of equation (2), should admit of being determined by the given conditions of the problem. Before giving the details of the method it is necessary to state the meanings of the literal symbols.

The resolved parts of the velocity being u, v, w at the point xyz at the time t,

$$d\phi = udx + vdy + wdz.$$

The attractions of the earth and moon at the unit of distance being respectively G and m, the impressed forces X, Y, Z are the resolved parts of the forces

$$-\frac{\mathrm{G}}{r^2}, \quad -\frac{m}{\mathrm{R}^2}, \quad \text{and} \quad \frac{m}{r'^2},$$

r' being the distance of the particle at xyz from the moon. The angular distance of the moon westward from the meridian of Greenwich at the time t reckoned from the Greenwich transit is μt. If λ be the north latitude, and θ the longitude westward, of the point xyz distant by r from the earth's centre,

$$x = r\cos\lambda\cos\theta, \qquad y = r\cos\lambda\sin\theta, \qquad z = r\sin\lambda.$$

After transforming by these formulæ the rectangular coordinates in equation (1) into the polar coordinates r, θ, λ, for certain specified reasons the author assumed that

$$r\phi = f(r)\cos^2\lambda\sin 2(\theta - \mu t),$$

and then found that equation (1) is satisfied by this value of $r\phi$ if the form of f be determined by integrating the equation

$$\frac{d^2f}{dr^2} - \left(6 - \frac{4\mu^2}{a^2}\right)f = 0.$$

This integration gave, after omitting the extremely small quantity $\frac{16\mu^2}{25a^2}$, the following value of ϕ, containing two arbitrary constants:

$$\phi = (\mathrm{C}r^2 + \mathrm{C}'r^{-3})\cos^2\lambda\sin(2\theta - \mu t).$$

The remainder of the reasoning depends altogether on this value of ϕ, which was considered by the author to be indispensable for the solution of the problem of atmospheric tides, and, as far as he was aware, had not been before employed for that purpose.

For determining the three arbitrary quantities there are three conditions. That introduced by the integration of equation (2) is determined by the condition that at either pole of the earth the density has a constant value, because, as may be inferred from the expression for ϕ, the aërial columns having their bases at the poles are motionless. A second condition is, that at the earth's surface the vertical velocity, $\frac{d\phi}{dr}$, is always zero; so that if b be the earth's radius, $\mathrm{C}' = \frac{2b^5\mathrm{C}}{3}$.

The third condition necessarily has reference to the circumstances of the fluid at its *superior* boundary, respecting which the author argues as follows:—

That the height of the atmosphere is limited may be inferred from the consideration that, by the continual diminution of the density with the distance from the earth's surface, the upward molecular repulsion must eventually be no greater than the downward acceleration of gravity, in which case there can be no further upward action, and the fluid terminates by an abnormal degradation of the density down

to zero at the extreme limit. The particles within the superficial stratum subjected to this disturbance are maintained in equilibrium by the combined action of molecular repulsion and the earth's attraction, till at a small distance from the extreme limit, where the abnormal variation of density ceases, the density is such as might result from a very small constant pressure applied at all points of a surface bounding a terminal density of finite value. (Views of this kind respecting the condition of the atmosphere at its superior limit were entertained by Poisson.) On these principles it is easy to find a mathematical relation between the terminal density and the height of the atmosphere. The author has, in fact, made the calculation on the supposition that the atmosphere is 60 miles high, and obtains a terminal density equal to six-millionths of that at the earth's surface.

According to the above views a particle at the superior boundary may be supposed to remain at the surface, and to be of the same density, in successive instants. This condition is expressed by equating the complete differential coefficient $\left(\frac{dp}{dt}\right)$ to zero. By means of this additional equation the value of the constant C can be calculated on assuming a certain height for the atmosphere. Supposing the height to be 60 miles, the author obtains $C=0\cdot000000830\,\mu$.

The arbitrary quantities being determined, the following results are readily obtained :—

Height of tide above the polar column, expressed in feet,

$$=1\cdot084\cos^2\lambda+1\cdot275\cos^2\lambda\cos 2(\theta-\mu t).$$

At the equator, where $\lambda=0$, difference between high and low tide $=2\cdot55$ feet.
Excess of barometer-reading above that at the pole, expressed in inches,

$$=0\cdot00117\cos^2\lambda+0\cdot00139\cos^2\lambda\cos 2(\theta-\mu t).$$

At the equator the maximum difference of the barometer-readings $=0\cdot00278$ in.

The data employed in calculating these coefficients were :—

$$\frac{m}{\mathrm{G}}=\frac{1}{70},\quad \frac{b}{\mathrm{R}}=\frac{1}{60\cdot3},\quad \frac{\mu^2 a}{g}=\frac{79^2}{82^2}\times\frac{1}{289},$$

the density of air $=0\cdot0013$, the density of mercury $=13\cdot568$.

The above determination of the maximum difference of barometer-readings at the equator admits of comparison with the results of barometric observations made at St. Helena and at Singapore, as given in p. 129 of the Philosophical Transactions for 1852. These results agree with the theory in placing the high tide immediately under the moon; but the maximum difference of readings is 0·00365 in. at St. Helena and 0·00570 in. at Singapore. Both consequently are in excess of the theoretical value 0·00278 in. But it is to be remarked that the latter depends on the assumption that the atmosphere is 60 miles high; if it had been supposed of less height, say 40 miles, there would have been a closer agreement between the observed and theoretical values.

The author's theory accounts in a remarkable manner for the fact that although for the atmosphere high tide occurs under the moon, there is reason to say that for a general ocean of the uniform depth of three or four miles it would be low tide under the moon. The explanation given by the theory is, that there is a certain depth of ocean or height of atmosphere for which the tide becomes infinite, namely, when the rate of propagation of waves, as due to the earth's attraction, is equal to the rate of the moon's relative rotation about the earth. In that case the tide would be accumulative, and might be of unlimited amount. This critical depth, or height, is shown by the theory to be about 8·4 miles for each fluid. It is because the actual mean depth of the ocean is less, and the actual height of the atmosphere greater, than this critical value, that the ocean-tide under the moon is the opposite of the atmospheric tide.

Remarks on Aërial Currents. By Prof. Colding.

On Wet- and Dry-bulb Formulæ. *By* Prof. J. D. Everett, *F.R.S.E.*

The author said August, Apjohn, and Regnault have investigated formulæ for determining the dew-point, by calculation, from the temperatures of the dry- and wet-bulb thermometers; but Regnault's experiments on the specific heat of air were not performed till a later date, and all these authors have adopted, in their investigations, the value obtained by Delaroche and Berard, which is ·267, whereas the correct value is ·237. But when this correct value is introduced into Regnault's formula, the discrepancies which he found to exist between calculation and observation are increased, and amount, on an average, to about 25 per cent. of the difference between wet-bulb temperature and dew-point. August and Apjohn erred in assuming that all the air which gives heat to the wet bulb (1) falls to the temperature of the wet bulb, and (2) becomes saturated. These two false assumptions would jointly produce no error in the result, if the depressions of temperature in the different portions of air affected were exactly proportional to their increments of vapour-tension, and if some of the air were saturated at the temperature of the wet bulb. But it is probable that, when there is little or no wind, the mass of air which falls sensibly in temperature is larger than that which receives a sensible accession of vapour, and that, in high wind, the supposition that some of the air has fallen to the temperature of the wet bulb is more nearly fulfilled than the supposition that it has taken up enough vapour to saturate it. The effect of radiation, which is ignored in the formulæ, tends in the same direction as these two inequalities, and all three are roughly compensated by attributing to air a greater specific heat than it actually has. The discrepancies above referred to are thus explained.

On the General Circulation and Distribution of the Atmosphere. *By* Professor J. D. Everett, *F.R.S.E.*

The object of this paper was to call the attention of meteorologists to a theory which is jointly due to Prof. James Thomson of Belfast, and Mr. Ferrel of Boston, U.S.A., and which gives the only satisfactory account of the grand currents of the atmosphere, and of the distribution of barometric pressure over the earth's surface, the irregularities arising from the distribution of land and water being neglected. Independent proofs were also given of some of Mr. Ferrel's results.

In virtue of the earth's rotation, with angular velocity ω, a body, in latitude λ, moving along the earth's surface with relative linear velocity v, tends to describe on the earth's surface a curve concave to the body's right in the northern and to its left in the southern hemisphere, the radius of cuvature of the concavity being $\frac{6850\,v}{\sin\lambda}$ feet, if the velocity is in feet per second. The deflection from a parallel of latitude into a great circle is usually negligible in comparison, being represented by the curvature of a circle of radius $R \cot\text{an}\,\lambda$, where R is the earth's radius.

To keep the moving body in a great circle, or in a parallel of latitude, requires a constraining force per unit of mass equal to $2\,\omega \sin\lambda\,.\,v$, which if the foot and second be units, is $\frac{v \sin\lambda}{6850}$; and this formula applies alike to all horizontal directions of motion.

The air over the extra-tropical parts of the earth has, upon the whole, a relative motion towards the east, and therefore presses towards the tropics with a force which can be computed by the above formula, if the eastward velocity at each parallel is known. If v denote this velocity at any parallel, in feet per second, the increase of pressure per degree of latitude at that parallel is $\cdot 0019\,v \sin\lambda$ inches of mercury. This is sufficient to account for the observed increase of pressure from the poles to the tropics, which may be roughly stated at ·01 inch per degree.

Between the tropics, the general movement of the air, relative to the earth, is towards the west, and the increase of pressure is therefore from the equator towards the tropics.

If any stratum of air have less than the average eastward or westward velocity (relative to the earth) which prevails through the strata above it, it will

not be able to resist the differential pressure from or towards the equator which their motion produces. For this reason, the lowest stratum of air, having its velocity relative to the earth kept down by friction, generally moves from the tropical belts of high barometer to the regions of low barometer at the poles and equator. This is the origin of our S.W. winds, and of the prevalent N.W. winds of the Southern oceans, which must be regarded as constituting an undercurrent towards the pole, beneath a topmost current, also towards the pole, and a middle return current. Between the tropics, on the other hand, the motion thus generated in the lowest stratum of air coincides with the motion due to difference of temperature, and this is probably the reason why the trade-winds are more constant than the winds of the temperate zones.

Excess of temperature and moisture in the equatorial regions is unquestionably the prime mover of the winds, as has long been believed; but the *crossing of the winds* at the tropic, which has often been coupled with it, is a physical impossibility.

The tendency of a moving mass of air to swerve to its own right in the northern hemisphere explains the well-established law (Buys Ballot's), that the wind, instead of blowing at right angles to the isobaric lines, and so running down the steepest gradient, usually makes an angle of only 20° or 30° with these lines, keeping the region of lower barometer on its left. The rotation of cyclones is an example of this law; and the pressure which the spirally inflowing streams exert to their own right in virtue of the earth's rotation is the main cause of the excessive central depression.

Reference was made to Prof. J. Thomson's paper in the British Association Report for 1857, and to papers by Mr. Ferrel in the 'American Mathematical Monthly for 1860, and in 'Nature,' July 20, 1871.

Observations Physiques en Ballon. *By* M. Janssen.

The Influence of the Moon on the Rainfall. *By* W. Pengelly, *F.R.S. &c.*

The author commenced by stating that though many of the popular beliefs respecting "The Moon and the Weather" were no doubt utterly untenable, Sir J. Herschel and M. Arago concurred in the opinion that, on the whole, the rainfall was somewhat below the general average about the time of full moon, and that the fact was ascribable to the effect of the solar heat *absorbed* by the moon and *radiated* by her to us. He then proceeded to show that the heat thus received by us must be greatest when, or very soon after, the moon was full, when she was in perigee, and (in the northern hemisphere) when she had north declination; that the effect of this heat would be a diminution of the rainfall, not during the *lunation* as a whole, but during a certain portion of it, and therefore an augmentation during some other period; that the effect would be variable and never considerable; and that in the northern hemisphere it would be a maximum when the moon was, at one and the same time, full, in perigee, and in her highest north declination. The paper was illustrated with several tables and diagrams based on rainfall observations made at Torquay during eighty-seven complete *lunations* ending with January 19, 1871.

The following were amongst the conclusions with which the paper closed:—

No indication of the moon's influence on the rainfall can be detected in the data furnished by an isolated *lunation*, or by even a few successive *lunations*.

Though it may be doubted whether the rainfall statistics of a period shorter than that in which the moon's nodes complete a revolution, or of a solitary locality, would justify general inferences, the data under discussion appear to indicate that, in the long run, the moon does somewhat influence the rainfall; that on the average the dry period of a *lunation* extends from the first day before full moon to the first day before the third quarter, and the wet period from the day of the first quarter to the second day before the full moon; that the moon's influence on the number of wet days is less marked; and that the rainfalls are, on the whole, rather least heavy when the moon has north declination, and when she is in perigee—all indications harmonizing well with physical considerations.

On the Inferences drawn by Drs. Magnus and Tyndall from their Experiments on the Radiant Properties of Vapour. By R. Russell.

The author agreed in the main with Tyndall's deductions. He endeavoured to show that vapour of water had no power of transmitting its radiant heat into space. This proposition was supported by arguments from various natural phenomena.

On Parhelia, or Mock Suns, observed in Ireland. By William A. Traill, *of the Geological Survey of Ireland.*

The author began by stating that the above phenomena were analogous to the paraselenæ or mock moons, and though of not unfrequent occurence in northern latitudes, were in these countries of great rarity. The phenomena observed by him were seen on the 28th of January, 1869, near the village of Strangford (Co. Down), lat. 54° 21′, long. 5° 35′, west of Greenwich, and first appeared as three brilliant suns situated in the same horizontal line, about 15° to 20° above the horizon, and of equal brightness. The two outer, or mock suns, gradually assumed the prismatic colours, and lengthening out joined above, thus forming the "ordinary halo," in which the red colour was nearest to the real sun. Concentric and exterior to it was another prismatic halo, the "extraordinary halo," which was rather fainter, in which also the red colour was innermost.

Touching this latter externally was the "circumzenithal halo," which was by far the most brilliant of the three, lying as if horizontally overhead. In this likewise the red colour was next the sun, thus forming the outer periphery of the halo. The phenomena began a little after 2 P.M., and lasted only for about half an hour, attaining its greatest splendour at 2^h 20^m P.M.

Throughout the duration of the phenomena the sky was of a clear blue colour, and almost unobscured; a few light fleecy clouds were, however, drifting northward, slight "cirrus" clouds stretched across part of the sky, from E. to W., and throughout the whole time the points where the mock suns had first appeared continued the brightest.

With regard to the state of the weather at the time, the day was mild and fine, no rain falling till the evening. The sun was warm, but a cold southerly wind prevailed. The moon was full on the previous day, and exceptionally high spring-tides occurred along the N.E. portion of the Irish coast.

The barometer fell rapidly ·7 inch within twelve hours. The wind veered round gradually through 140°, and increased in velocity from 6 to 38 miles an hour, the thermometer ranging from 42° to 46°, and towards evening the rain descended in torrents*. The succeeding ten days or fortnight was characterized by excessively bad weather, rain, and storms.

The author lastly touched on the different theories by which these phenomena could be most easily accounted for.

The Progress of Science.

Government Action on Scientific Questions. By Lieut.-Col. A. Strange, *F.R.S., F.R.A.S.*

The author called attention to the number, variety, and importance of those national duties, involving Science, which can be performed by the Executive Government alone. He pointed out that the English Government possesses as yet no provision for regulating the performance of these duties in a systematic manner. He maintained that the requisite provision must consist of two additions to the existing administration, neither of which, however, unaccompanied by the other would suffice—namely, first, a Minister of Science; and, second,

* From Observations at the Armagh Observatory.

a permanent Consultative Council, to advise the various departments through the Minister. His purpose was not to endeavour to uproot the existing system, but to graft upon it additions demanded by experience and the progress of knowledge. Assuming that the Minister would be appointed for his station, parliamentary ability, and political influence, he would need advisers, who should be a permanent, well-paid, and therefore a responsible Council of Science, representing all the main branches of science, the different arms of the military and naval services, commerce, agriculture, and the engineering profession. The Council should be quite independent of political influences. The author described the mode of election to the Council which he proposed, and in which he would give a certain voice to the Scientific Societies. The duties of the Council would be—first, to advise the Government on all questions arising in the ordinary routine of administration submitted to it by the various departments; second, to advise the Government on special questions, such as the founding of new scientific institutions and the modification or abolition of old ones, the sanctioning of scientific expeditions and applications for grants for scientific purposes; third, to consider and decide upon inventions tendered to Government for the use of the State; and, fourth, to conduct or superintend the experiments necessary to enable it to perform these duties. This would not entirely relieve the Government of all responsibility in scientific matters. The advantages to the nation accruing from a sound and comprehensive administration of science were incalculable.

The author referred, for fuller particulars regarding the subject, to his paper "On the Necessity for a Permanent Commission on State Scientific Questions," read before the Royal United Service Institution on the 15th of May last, and published in No. 64 of the Journal of the Institution.

Obstacles to Science-Teaching in Schools. By the Rev. W. Tuckwell.

After describing the slow progress made in scientific teaching since the Report of the Public Schools' Commission in 1864, and declaring that the first-class English schools teaching science systematically at the present momentcan b e counted on the fingers of one hand, the author proceeded to show that the head masters were not altogether to be blamed for this state of things.

They have inherited an order of tuition some hundred years old, fortified with minute, unbroken venerable traditions, looked upon for ages past as the supreme instrument and test of intellectual power, whole and complete in itself, supported by immense experience, worked by tried machinery. Into the midst of this well-mapped, well-proved system is thrust a strange and foreign subject, comprising many branches, and demanding multifold appliances, whose value as a mental weapon they have had no means of testing; they are called upon to surrender to this a portion of the time which already seems too short for other work, and to inaugurate a department of school labour over which they can exercise no sort of supervision or control. They ask for guidance in the new arrangements which they are called upon to form; whether any one department is educationally fundamental to the rest; whether sciences of experiment should precede or follow those of observation; what portions of the old course are to be abandoned; how far the Universities, which in many cases stamp the practical value of their work, will recognize such abandonment. They look round for accredited teachers and approved text-books, for enlightenment as to the amount of apparatus and its cost, for details of teaching and of testing, and they look in vain. They must fall back upon their own moral consciousness, for no help is tendered to them from without. I place this helplessness of head masters first on the list of obstacles which we have to chronicle; and I plead, for the moment, in their behalf, almost more than in behalf of science. For their attitude is frank and cordial; they are prepared as a body to meet the demands of the scientific public loyally and with all their might. If those who are pressing modern subjects on them will entertain their just appeal and try to understand their difficulties, they will prove the best auxiliaries science can hope to gain; for they will bring to this new department of their work the same energy and wisdom, the same self-sacrificing impartial zeal, which have

already won for them the deserved esteem of the community; but if we fail to work in harmony with them, their want of sympathy and interest will be simply fatal to our schemes.

Next to this helplessness of head masters came the difficulty of obtaining properly trained and certificated science-teachers. With the admirable German system, comprising special examination of Candidates for Masterships, not only in knowledge, but in teaching power, together with a year of trial in some large school before entering on their work, was compared the insufficient test offered by the English University Degree, a high test, no doubt, of intelligence and knowledge, but not of power to communicate knowledge or to infuse intelligence. Third in rank amongst the obstacles to be surmounted was placed the cost of paying science masters; and the School Commissioners, now redistributing the endowments of the country, were urged to set apart funds for science-teaching in every large school, and to insist on their being faithfully expended for the purpose. The necessity of having good teachers was then dwelt on. The first condition of success in scientific, as of other teaching, is obviously the teacher. He must be a man thorough in his special knowledge, and, if his special knowledge is to be well balanced in reference to other subjects, of the widest general culture. He must not spend all his time in teaching, but must have leisure to prepare lessons and experiments. He must possess the delicate art of handling many pupils, the force of manner which attracts them, the enthusiasm which puts and keeps them *en rapport* with him, the insight which reads their minds, the tact which can preserve discipline without checking inquiry, and, possessing all this and more, he must be well and highly paid.

An exact estimate was offered of the cost of apparatus; and the value of workshops, museums, and other accessories of the kind was dwelt upon.

After glancing at the action of the universities, the author touched on a grave item in the catalogue of difficulties. Granting that scientific teaching is essential to a perfect education, the anxious question meets us—How is it to be inserted in the curriculum of an established school? We are told that, to meet the demands of University competition, the highest pressure is already put upon the time and brains of boys; and that if four hours a week are to be accepted as the minimum demand of science, classical work must suffer. And, in order to solve this problem, some well-known schools have instituted a system of bifurcation, to which the author was opposed. If linguistic training is bad without the rationalizing aid of scientific study, no less is exclusive science bad when divorced from the refining society of literature and philology; and an admission that certain institutions stunt particular faculties is oddly followed by a device which causes each to work unchecked. The difficulty must be met fairly, and on premises which scholars as well as *savans* can understand. It must be met by asking whether in purely classical schools no time is wasted; why it is that in the lower forms a boy takes years to master what a clever tutor teaches in a few months at home; why the weapon of analysis, which opens every other chamber of human knowledge, should be discarded in the case of scholarship alone; whether unattractiveness is an inherent vice in Greek and Latin only, or whether, if judicious method wakens pleasure and keeps alive attention, that of itself is not economy of time; whether, lastly, the day has not arrived when Greek and Latin verse-making may not be allowed to disappear. After having written some thousand Greek and Latin verses in his own school-days, the author pronounced them waste of time, and protested against them altogether. Their elimination from our school system will be clear gain in itself, and will set free at once a much larger amount of time than is demanded for the prosecution of natural science.

After enumerating at some length the details essential to the giving a fair place to science in education, the paper ended as follows:—"The summary of what I have to say is this, that our schools, in their readiness to establish science, must be aided from without. All questions of funds, of apparatus, of teachers, of selected text-books, of coordinated subjects, of University influence, and of united action come to the same point at last. We must have central leadership, at once commanding and intelligent, if the introduction of science into our schools is to be simultaneous and effective. The question has passed out of the realm of general

discussion; it is ripe, if ever a question was, for detailed and practical settlement. There must be within this Association, there must be within this room, men qualified in all respects to appreciate the nature of our difficulties, to formulate rules for our guidance, to press our pecuniary needs on those who are for a time the bursars of our educational endowments, to watch and influence the action of the Universities, as on other points, so especially in the projected 'Leaving Examinations.' To them I confidently appeal. I appeal on behalf of countless schools, which, ready to admit reform, are helpless to initiate it. I appeal on behalf of those few schools which *have* initiated it, and are endeavouring courageously and honestly, but with little of useful concert, with much of wasted force, to work it out. Let it once be announced to the educational community that a committee of distinguished men, having at heart not merely scientific interests, but the interests of the Universities and the Schools, has been armed by this Association to counsel and to assist, to recommend and to accredit, to harmonize and to combine, to become, in short, the recognized representatives and controllers of scientific education, and they will not lack grateful clients, or attain inadequate results. If science is to flourish in the land, preliminary knowledge and training, bestowed with care upon our boyhood, must leave our manhood free for original research. If our English education is to be abreast of continental teaching, one half of our mental faculties must no longer be suffered to lie dormant. To have removed this great reproach, and to have helped this great reform, will be an achievement worthy to take high rank even amongst those splendid services to science and to the community which give lustre to the British Association."

CHEMISTRY.

Address by Professor Andrews, *F.R.S. L. & E., President of the Section.*

Amidst the vicissitudes to which scientific theories are liable, it was scarcely to be expected that the discarded theory of Phlogiston should be resuscitated in our day and connected with one of the most important generalizations of modern science. The phlogistic theory, elaborated nearly two hundred years ago by Beecher and Stahl, was not, it now appears, wholly founded in error; on the contrary, it was an imperfect anticipation of the great principle of energy, which plays so important a part in physical and chemical changes. The disciple of Phlogiston, ignorant of the whole history of chemical combination, connected, it is true, his phlogiston with one only of the combining bodies, instead of recognizing that it is eliminated by the minor of all. "There can be no doubt," says Dr. Crum Brown, who first suggested this view, "that potential energy is what the chemists of the 17th century meant when they spoke of phlogiston." "Phlogiston and latent heat," playfully remarks Volhard, "which formerly opposed each other in so hot a combat, have entered into a peaceful compact; and, to banish all recollection of their former strife, have assumed in common the new name of energy." But, as Dr. Odling well remarks, "in interpreting the phlogistic writings by the light of modern doctrine, we are not to attribute to their authors the precise notion of energy which now prevails. It is only contended that the phlogistians had in their time possession of a real truth in nature, which, altogether lost sight of in the intermediate period, has since crystallized out in a definite form."

But whatever may be the true value of the Stahlian views, there can be no doubt that the discoveries which have shed so bright a lustre round the name of Black mark an epoch in the history of science, and gave a mighty impulse to human progress. A recent attempt to ignore the labours of Black and his great contemporaries, and to attribute the foundation of modern chemistry to Lavoisier alone, has already been amply refuted in an able inaugural address delivered a short time ago from the Chair formerly occupied by Black. The statements of Dr. Crum Brown may, indeed, be confirmed on the authority of Lavoisier himself. Through the kindness of Dr. Black's representatives I have been permitted to

examine his correspondence, which has been carefully preserved, and I have been so fortunate as to find in it three original letters from Lavoisier to Dr. Black. They were written in 1789 and 1790, and they appear to comprise the whole of the correspondence on the part of Lavoisier which passed between those distinguished men. Some extracts from these letters were published soon after Dr. Black's death by his friends Dr. Adam Ferguson and Dr. Robison; but the letters themselves, as far as I know, have never appeared in an entire form. I will crave permission to have them printed as an appendix to this address*. Lavoisier, it will be seen, addresses Black as one whom he was accustomed to regard as his master, and whose discoveries had produced important revolutions in science. It may, indeed, be said with truth that Lavoisier completed the foundation on which the grand structure of modern chemistry has since arisen; but Black, Priestley, Scheele, and Cavendish were before Lavoisier, and their claims to a share in the great work are not inferior to those of the illustrious French chemist.

Among the questions of general chemistry, few are more interesting, or have of late attracted more attention, than the relations which subsist between the chemical composition and refractive power of bodies for light. Newton, it will be remembered, pointed out the distinction between the refractive power of a medium and its refractive index, and gave for the former the expression $\frac{\mu_2-1}{d}$, where μ is the refractive index, and d the density of the refracting medium. Sir J. Herschel, anticipating later observations, remarked, in 1830, that Newton's function only expresses the intrinsic refractive power on the supposition of matter being infinitely divisible; but that if material bodies consist of a finite number of atoms, differing in weight for different substances, the intrinsic refractive power of the atoms of any given medium will be the product of the above function by the atomic weight. The same remark has since been made by Berthelot. Later observations have led to an important modification in the form of Newton's function. Beer showed that the experiments of Biot and Arago, as well as those of Dulong, on the refractive power of gases, agree quite as well with a simpler expression as with that given by Newton; and Gladstone and Dale proposed in 1863 the formula $\frac{\mu-1}{d}$ as expressing more accurately than any other the results of their experiments on the refractive power of liquids. The researches of Landolt and Wüllner have fully confirmed the general accuracy of the new formula. An important observation made, about twenty years ago, by Delffs has been the starting-point for all subsequent investigations on this subject. Delffs remarked that the refractive indices of the compound ethers increase with the atomic weight, and that isomeric ethers have the same refractive indices. The later researches of Gladstone and of Landolt have, on the whole, confirmed these observations, and have shown that the specific refractive power depends chiefly on the atomic composition of the body, and is little influenced by the mode of grouping of the atoms. These inquiries have gone further, and have led to the discovery of the refraction-equivalents of the elements. By comparing the refractive power of compound bodies differing from one another by one or more atoms of the same element, Landolt succeeded in obtaining numbers which express the refraction-equivalents of carbon, hydrogen, and oxygen; and corresponding numbers have been obtained for other elements by Gladstone and Haagen. The whole subject has been recently discussed and enriched with many new observations in an able memoir by Gladstone. As might be expected in so novel and recondite a subject, some anomalies occur which are difficult to explain. Thus hydrogen appears in different classes of compounds with at least two refraction-equivalents, one three times as great as the other; and the refraction-equivalents of the aromatic compounds and their derivatives, as given by observation, are in general higher than the calculated numbers.

A happy modification of the ice-calorimeter has been made by Bunsen. The principle of the method (to use as a measure of heat the change of volume which ice undergoes in melting) had already occurred to Herschel, and, as it now appears, still earlier to Hermann; but their observations had been entirely overlooked by physicists, and had led to no practical result. Bunsen has, indeed, clearly pointed

* Ordered by the General Committee to be printed among the Reports.

out that the success of the method depends upon an important condition, which is entirely his own. The ice to be melted must be prepared with water free from air, and must surround the source of heat in the form of a solid cylinder frozen artificially *in situ.* Those who have worked on the subject of heat know how difficult it is to measure absolute quantities with certainty, even where relative results of great accuracy may be attained. The ice-calorimeter of Bunsen will therefore be welcomed as an important addition to our means of research. Bunsen has applied his method to determine the specific heats of ruthenium, calcium, and indium, and finds that the atomic weight of indium must be increased by one half in order to bring it into conformity with the law of Dulong and Petit. He has also made a new determination of the density of ice, which he finds to be 0·9167.

In a report on the Heat of Combination, which was made to this Association in 1849, the existence of a group of isothermal bases was pointed out. "As some of the bases" (potash, soda, baryta, strontia), it was remarked, "form what we may perhaps designate an isothermal group, such bases will develope the same or nearly the same heat in combining with an acid, and no heat will be disengaged during their mutual displacements." The latest experiments of Thomsen have given a remarkable extension to this group of isothermal bases. He finds that the hydrates of lithium, thallium, calcium, and magnesium produce, when all corrections are made, the same amount of heat, on being neutralized by sulphuric acid, as the four bases before mentioned. The hydrate of tetramethylammonium belongs to the same class of bases. Ethylamin, on the other hand, agrees with ammonia, which, as has been long known, gives out less heat in combining with the acids than potash or soda. An elaborate investigation of the amount of heat evolved in the combustion of coal of different kinds has been made by Scheurer-Kestner and Meusnier, accompanied by analyses of the coal. Coal rich in carbon and hydrogen disengages more heat in burning than coal in which those elements are partially replaced by oxygen. After deducting the cinders, the heat produced by the combustion of 1 gramme of coal varied from 8215 to 9622 units.

Tyndall has given an extended account of his experiments on the action of a beam of strong light on certain vapours. He finds that there is a marked difference in the absorbing-power of different vapours for the actinic rays. Thus nitrite of amyl in the state of vapour absorbs rapidly the rays of light competent to decompose it, while iodide of allyl in the same state allows them freely to pass. Morren has continued these experiments in the south of France, and among other results he finds that sulphurous acid is decomposed by the solar beam.

Roscoe has prosecuted the photo-chemical investigations which Bunsen and he began some years ago. For altitudes above 10 degrees, the relation between the sun's altitude and the chemical intensity of light is represented by a straight line. Till the sun has reached an altitude of about 20 degrees, the chemical action produced by diffused daylight exceeds that of the direct sunlight; the two actions are then balanced; and at higher elevations the direct sunlight is superior to the diffused light. The supposed inferiority of the chemical action of light under a tropical sun to its action in higher latitudes proves to be a mistake. According to Roscoe and Thorpe, the chemical intensity of light at Pará under the equator in the month of April is more than three times greater than at Kew in the month of August.

Hunter has given a great extension to the earlier experiments of Saussure on the absorptive power of charcoal for gases. Cocoanut-charcoal, according to Hunter's experiments, exceeds all other varieties of wood-charcoal in absorptive power, taking up at ordinary pressures 170 volumes of ammonia and 69 of carbonic acid. Methylic alcohol is more largely absorbed than any other vapour at temperatures from 90° to 127°; but at 159° the absorption of ordinary alcohol exceeds it. Cocoanut-charcoal absorbs forty-four times its volume of the vapour of water at 127°. The absorptive power is increased by pressure.

Last year two new processes for improving the manufacture of chlorine attracted the attention of the Section: one of these has already proved to be a success; and I am glad to be able to state that Mr. Deacon has recently overcome certain difficulties in his method, and has obtained a complete absorption of the chlorine. May we hope to see oxygen prepared by a cheap and continuous process from

atmospheric air? With baryta the problem can be solved very perfectly, if not economically. Another process is that of Tessier de Mothay, in which the manganate of potassium is decomposed by a current of superheated steam, and afterwards revived by being heated in a current of air. A company has lately been formed in New York to apply this process to the production of a brilliant house-light. A compound Argand burner is used, having a double row of apertures; the inner row is supplied with oxygen, the outer with coal-gas or other combustible. The applications of pure oxygen, if it could be prepared cheaply, would be very numerous; and few discoveries would more amply reward the inventor. Among other uses it might be applied to the production of ozone free from nitric acid by the action of the electrical discharge, and to the introduction of that singular body, in an efficient form, into the arts as a bleaching and oxidizing agent. Tessier de Mothay has also proposed to prepare hydrogen gas on the large scale by heating hydrate of lime with anthracite.

We learn from the history of metallurgy that the valuable alloy which copper forms with zinc was known and applied long before zinc itself was discovered. Nearly the same remark may be made at present with regard to manganese and its alloys. The metal is difficult to obtain, and has not in the pure state been applied to any useful purpose; but its alloys with copper and other metals have been prepared, and some of them are likely to be of great value. The alloy with zinc and copper is used as a substitute for german silver, and possesses some advantages over it. Not less important is the alloy of iron and manganese prepared according to the process of Henderson, by reducing in a Siemens's furnace a mixture of carbonate of manganese and oxide of iron. It contains from 20 to 30 per cent. of manganese, and will doubtless replace to a large extent the spiegeleisen now used in the manufacture of Bessemer steel.

The classical researches of Roscoe have made us acquainted for the first time with metallic vanadium. Berzelius obtained brilliant scales, which he supposed to be the metal, by heating an oxychloride in ammonia; but they have proved to be a nitride. Roscoe prepared the metal, by reducing its chloride in a current of hydrogen, as a light grey powder, with a metallic lustre under the microscope. It has a remarkable affinity both for nitrogen and silicon. Like phosphorus, it is a pentad, and the vanadates correspond in composition to the phosphates, but differ in the order of stability at ordinary temperatures, the soluble tribasic salts being less stable than the tetrabasic compounds.

Sainte-Claire Deville, in continuation of his researches on dissociation, has examined the conditions under which the vapour of water is decomposed by metallic iron. The iron, maintained at a constant temperature, but varying in different experiments from 150° C. to 1600° C., was exposed to the action of vapour of water of known tension. It was found that for a given temperature the iron continued to oxidize, till the tension of the hydrogen formed reached an invariable value. In these experiments, as Deville remarks, iron behaves as if it emitted a vapour (hydrogen), obeying the laws of hygrometry. An interesting set of experiments has been made by Lothian Bell on the power possessed by spongy metallic iron of splitting up carbonic oxide into carbon and carbonic acid, the former being deposited in the iron. A minute quantity of oxide of iron is always formed in this reaction.

The fine researches of Graham on the colloidal state have received an interesting extension by Reynolds's discovery of a new group of colloid bodies. A solution of mercuric chloride is added to a mixture of acetone and a dilute solution of potassium hydrate till the precipitate which at first appears is redissolved, and the clear liquid poured upon a dialyzer which floated upon water. The composition of the colloid body thus obtained in the anhydrous state was found to be $\left((CH_3)_2CO\right)_2 Hg_3 O_3$. The hydrate is regarded by Reynolds as a feeble acid, even more readily decomposed than alkaline silicates. A solution containing only five per cent. forms a firm jelly when heated to 50° C. Analogous compounds were formed with the higher members of the fatty ketone series. In the same direction are the researches of Marcet on blood, which he finds to be a strictly colloid fluid containing a small proportion of diffusible salts.

In organic chemistry the labours of chemists have been of late largely directed

to a group of hydrocarbons which were first discovered among the products of the destructive distillation of coal or oil. The central body round which these researches have chiefly turned is benzol, whose discovery will always be associated with the name of Faraday. With this body naphthalin and anthracene form a series, whose members differ by $C_4 H_2$, and their boiling-points by about 140°. The recent researches of Liebermann have proved, as was before suspected, that chrysene is a fourth member of the same series. I may add that ethylene, which boils at about $-70°$, corresponds in composition and boiling-point to a lower member of the same series. Kekulé propounded some time ago with great clearness the question as to whether the six atoms of hydrogen in benzol are equivalent, or, on the contrary, play dissimilar parts. According to the first hypothesis, there can be only one modification of the mono- and penta-derivatives of benzol; while three modifications of the bi-, tri-, and tetra-derivatives are possible. On the second hypothesis, two modifications of the mono-derivatives are possible, and in general a much larger number of isomeric compounds than on the first hypothesis. Such is the problem which has of late occupied the attention of some of the ablest chemists of Germany, and has led to a large number of new and important investigations. The aromatic hydrocarbons, toluol, xylol, &c., which differ from one another by CH_2, have been shown by Fittig to be methyl derivatives of benzol. According to the first of the two hypotheses to which I have referred, only one benzol and one methyl benzol (toluol) are possible, and accordingly no isomeric modifications of these bodies have been discovered. But the three following members of the series ought each to be capable of existing in three distinct isomeric forms. The researches of Fittig had already established the existence of two isomeric compounds having the formula $C_8 H_{10}$,—methyl-toluol (obtained synthetically from toluol) and isoxylol (prepared by the removal of an atom of methyl from the mesytelene of Kane). The same chemist has since obtained the third modification, orthoxylol, by the decomposition of the paraxylylic acid. These three isomeric hydrocarbons may be readily distinguished from one another by the marked difference in the properties of their trinitro-compounds, and also by their different behaviour with oxidizing agents. Other facts have been adduced in support of the equality or homogeneity of position of the hydrogen atoms in benzol. Thus Hübner and Alsberg have prepared aniline, a mono-derivative, from different biderivatives, and have always obtained the same body. The latest researches on this subject are those of Richter.

Baeyer has prepared artificially picoline, a base isomeric with aniline, and discovered by Anderson in his very able researches on the pyridine series. Of the two methods described by Baeyer, one is founded on an experiment of Simpson, in which a new base was obtained by heating tribromallyl with an alcoholic solution of ammonia. By pushing further the action of the heat, Baeyer succeeded in expelling the whole of the bromine from Simpson's base in the form of hydrobromic acid, and in obtaining picoline. The same chemist has also prepared artificially collidine, another base of the pyridine series. To this list of remarkable synthetical discoveries, another of the highest interest has lately been added by Schiff—the preparation of artificial coniine. He obtained it by the action of ammonia on butyric aldehyde ($C_4 H_8 O$). The artificial base has the same composition as coniine prepared from hemlock. It is a liquid of an amber-yellow colour, having the characteristic odour and nearly all the usual reactions of ordinary coniine. Its physiological properties, so far as they have been examined, agree with those of coniine from hemlock; but the artificial base has not yet been obtained in large quantity, nor perfectly pure.

Valuable papers on alizarine have been published by Perkin and Schunck. The latter has described a new acid, the anthraflavic, which is formed in the artificial preparation of alizarine. Madder contains another colouring principle, purpurine, which, like alizarine, yields anthracene when acted on by reducing agents, and has also been prepared artificially. These colouring principles may be distinguished from one another, as Stokes has shown, by their absorption bands; and Perkin has lately confirmed by this optical test the interesting observation of Schunck, that finished madder prints contain nothing but pure alizarine in combination with the mordant employed.

Hofmann has achieved another triumph in a department of chemistry which he has made peculiarly his own. In 1857 he showed that alcohol bases, analogous to those derived from ammonia, could be obtained by replacement from phosphuretted hydrogen; but he failed in his attempts to prepare the two lower derivatives. These missing links he has now supplied, and has thus established a complete parallelism between the derivatives of ammonia and of phosphuretted hydrogen. The same able chemist has lately described the aromatic cyanates, of which one only, the phenylic cyanate (CO, C_6H_5, N), was previously known, having been discovered about twenty years ago by Hofmann himself. He now prepares this compound by the action of phosphoric anhydride on phenylurethane, and by a similar method he has obtained the tolylic, xylylic, and naphthylic cyanates.

Stenhouse had observed many years ago that when aniline is added to furfurol the mixture becomes rose-red, and communicates a fugitive red stain to the skin, and also to linen and silk. He has lately resumed the investigation of this subject, and has obtained two new bases, furfuraniline and furfurtoluidine, which, like rosaniline, form beautifully coloured salts, although the bases themselves are nearly colourless, or of a pale brown colour. The furfuraniline hydrochlorate ($C_{17}H_{19}O_2N_2Cl$) is prepared by adding furfurol to an alcoholic solution of aniline hydrochlorate containing an excess of aniline. We have also from Stenhouse a new contribution to the history of orcin, in continuation of his former masterly researches on that body. He has prepared the trinitroorcin ($C_7H_5(NO_2)_3O_2$), a powerful acid, having many points of resemblance to picric acid. In connexion with another research of Stenhouse made many years ago, it is interesting to find his formula for euxanthon, which was also that of Erdmann, confirmed by the recent experiments of Baeyer.

The interesting work of Dewar on the oxidation of picoline must not be passed over without notice. By the action of the permanganate of potassium on that body, he has obtained a new acid which bears the same relation to pyridine that phthalic acid does to benzol. Thorpe and Young have published a preliminary notice of some results of great promise which they have obtained by exposing paraffin to a high temperature in closed vessels. By this treatment it is almost completely resolved into liquid hydrocarbons, whose boiling-points range from 18° C. to 300° C. Those boiling under 100° have been examined, and consist chiefly of olefines. In connexion with this subject, it may be interesting to recall the experiments of Pelouze and Cahours on the Pennsylvanian oils, which proved to be a mixture of carbohydrogens belonging to the marsh-gas series.

An elaborate exposition of Berthelot's method of transforming an organic compound into a hydrocarbon containing a maximum of hydrogen has appeared in a connected form. The organic body is heated in a sealed tube, with a large excess of a strong solution of hydriodic acid, to the temperature of 275°. The pressure in these experiments Berthelot estimates at 100 atmospheres, but apparently without having made any direct measurements. He has thus prepared ethyl hydride (C_2H_6) from alcohol, aldehyde, &c., hexyl hydride (C_6H_{14}) from benzol. Berthelot has submitted both wood-charcoal and coal to the reducing action of hydriodic acid, and among other interesting results he claims to have obtained in this way oil of petroleum.

By the action of chloride of zinc upon codeia, Matthiessen and Burnside have obtained apocodeia, which stands to codeia in the same relation as apomorphia to morphia, an atom of water being abstracted in its formation. Apocodeia is more stable than apomorphia, but the action of reagents upon the two bases is very similar. As regards their physiological action, the hydrochlorate of apocodeia is a mild emetic, while that of apomorphia is an emetic of great activity. Other bases have been obtained by Wright by the action of hydrobromic acid on codeia. In two of these bases, bromotetracodeia and chlorotetracodeia, four molecules of the codeia are welded together, so that they contain no less than seventy-two atoms of carbon. They have a bitter taste, but little physiological action. The authors of these valuable researches were indebted to Messrs. Macfarlane for the precious material upon which they operated.

We are indebted to Crum Brown and Fraser for an important work on a subject of great practical as well as theoretical interest,—the relation between chemical

constitution and physiological action. It has long been known that the ferrocyanide of potassium does not act as a poison on the animal system, and Bunsen has shown that the kakodylic acid, an arsenical compound, is also inert. Crum Brown and Fraser find that the methyl compounds of strychnia, brucia, and thebaia are much less active poisons than the alkaloids themselves, and the character of their physiological action is also different. The hypnotic action of the sulphate of methyl-morphium is less than that of morphia; but a reverse result occurs in the case of atropia, whose methyl and ethyl derivatives are much more poisonous than the salts of atropia itself.

Before proceeding to the subject of fermentation, I may refer to Apjohn's chemico-optical method of separating cane-sugar, inverted sugar, and grape-sugar from one another when present in the same solution, by observing the rotative power of the syrup before and after inversion, and combining the indications of the saccharometer with the results of an analysis of the same syrup after inversion. Heisch's test for sewage in ordinary water is also deserving of notice. It consists in adding a few grains of pure sugar to the water, and exposing it freely to light for some hours, when the liquid will become turbid from the formation of a well-marked fungus if sewage to the smallest amount be present. Frankland has made the important observation that the development of this fungus depends upon the presence of the phosphate, and that if this condition be secured, the fungus will appear even in the purest water.

The nature of fermentation, and in particular of the alcoholic fermentation, has been lately discussed by Liebig with consummate ability, and his elaborate memoir will well repay a careful perusal. Dr. Williamson has also given a most instructive account of the subject, particularly with reference to the researches of Pasteur, in his recent Cantor lectures. A brief statement of the present position of the question will therefore not be out of place here. It is now thirty-four years since Cagniard de La Tour and Schwann proved by independent observations that yeast-globules are organized bodies capable of reproduction by gemmation; and also inferred as highly probable that the phenomena of fermentation are induced by the development or living action of these globules. These views, after having fallen into abeyance, were revived and extended a few years ago by Pasteur, whose able researches are familiar to every chemist. Pasteur, while acknowledging that he was ignorant of the nature of the chemical act, or of the intimate cause of the splitting up of sugar in the alcoholic fermentation, maintained that all fermentations properly so called are correlative with physiological phenomena. According to Liebig, the development and multiplication of the yeast-plant or fungus is dependent upon the presence and absorption of nutriment, which becomes part of the living organism, while in the process of fermentation an external action takes place upon the substance, and causes it to split up into products which cannot be made use of by the plant. The vital process and the chemical action, he asserts, are two phenomena which in the explanation must be kept separate from one another. The action of a ferment upon a fermentable body he compares to the action of heat upon organic molecules, both of which cause a movement in the internal arrangement of the atoms. The phenomena of fermentation Liebig refers now, as formerly, to a chemico-physical cause,—the action, namely, which a substance in a state of molecular movement exercises upon another of highly complex constitution, whose elements are held together by a feeble affinity, and are to some extent in a state of tension or strain. Baeyer, who considers that in the alcoholic and lactic fermentations one part of the compound is reduced and another oxidized, adopts the view of Liebig, that the molecules of sugar which undergo fermentation do not serve for the nourishment of the yeast-plant, but receive an impulse from it. All are, however, agreed that fermentation is arrested by the death of the plant; and even a tendency to the acetous fermentation in wine may be checked, as Pasteur has shown, by heating the wine to a temperature a little below the boiling-point in the vessel in which it is afterwards to be kept.

I regret that the limits of an address like the present forbid me to pursue further this analysis of chemical work. Had they admitted of abridgment, I should gladly have described the elaborate experiments of Gore on hydrofluoric acid and the fluoride of silver. The important researches of Abel on explosive

compounds will be explained by himself in a lecture with which he has kindly undertaken to favour the Association. Mr. Tomlinson will also communicate to the Section some observations on catharism and nuclei, a difficult subject, to which he has of late devoted much attention; and I am also informed that we shall have important papers on recent improvements in chemical manufacture.

No one can be more painfully alive than myself to the serious omissions in the historical review I have now read, more particularly in organic chemistry, where it was wholly impossible to grapple with the large number of valuable works which even a few months produce. I cannot, however, refrain from bearing an humble tribute to the great ability and indomitable perseverance which characterize the labourers in the great field of organic chemistry. It would scarcely be possible to conceive any work more intelligently undertaken or more conscientiously performed than theirs, yet much of it, from its abstruse character, receiving little sympathy or encouragement except from the band of devoted men who have made this subject the chief pursuit of their lives. They will, however, find their reward in the consciousness that they have not lived in vain, but have been engaged, and successfully engaged, in the noble enterprise of extending for the benefit of the human family the boundaries of scientific knowledge. Nor is there any real ground for discouragement. Faraday, Graham, Magnus, and Herschel, who have left their impress on this age, were all distinguished chemical as well as physical discoverers; and the relations of the sciences are becoming every day so intimate that the most special research leads often to results of wide and general interest. No one felt this truth more clearly or illustrated it better in his writings than our lamented and distinguished friend Dr. Miller, whose presence used to cheer our meetings, and whose loss we all most sincerely deplore.

Facts developed by the Working of Hæmatite Ores in the Ulverstone and Whitehaven Districts from 1844–71. *By* Thomas Ainsworth.

On the Dichroism of the Vapour of Iodine. By Dr. Andrews, *F.R.S.*

The fine purple colour of the vapour of iodine arises from its transmitting freely the red and blue rays of the spectrum, while it absorbs nearly the whole of the green rays. The transmitted light passes freely through a red copper or a blue cobalt glass. But if the iodine vapour be sufficiently dense, the whole of the red rays are absorbed, and the transmitted rays are of a pure blue colour; they are now freely transmitted, as before, by the cobalt glass, but will not pass through the red glass. A solution of iodine in sulphide of carbon exhibits a similar dichroism, and according to its density appears either purple or blue when white light is transmitted through it. The alcoholic solution, on the contrary, is of a red colour, and does not exhibit any dichroism.

On the Action of Heat on Bromine. By Dr. Andrews, *F.R.S.*

If a fine tube is filled one half with liquid bromine and one half with the vapour of bromine, and after being hermetically sealed is gradually heated till the temperature is above the critical point, the whole of the bromine becomes quite opaque, and the tube has the aspect of being filled with a dark red and opaque resin. A measure of the change of power of transmitting light in this case may be obtained by varying the proportion of liquid and vapour in the tube. Even liquid bromine transmits much less light when heated strongly in an hermetically sealed tube than in its ordinary state.

Some Remarks upon the Proximate Analysis of Saccharine Matters. By Professor Apjohn, *F.R.S.*

On the Examination of Water for Sanitary purposes. By GUSTAV BISCHOF.

The principle of the method consists in evaporating 1 cub. centim. of the water to be examined in a cell formed by cementing a glass ring on a slip of plate glass, such as used for mounting microscopic objects. By means of certain appliances dust is effectually excluded during the evaporation. The temperature at which the samples are evaporated (40° to 45° C.) is regulated by a Kemp-Bunsen gas-regulator improved for the purpose by the author.

If *pure* water, such as we find naturally, be evaporated, one observes under the microscope in the residue essentially colourless, or nearly colourless, dendritic, branching, tree-like, and well-defined hexagonal and rhombohedral crystals of calcium carbonate. In the case of natural *impure* water, or if pure water be contaminated by adding minute quantities of either sewage or urine, the above crystals are no longer perceptible, and, according to the degree of impurity, their place is taken by more or less imperfectly defined yellowish-brown or red hexagonal or rhombohedral crystals of calcium carbonate, or by hexagonal twin-crystals, or triangles with rounded angles, or, finally, drops of fat and the so-called dumb-bells (which latter are either fatty matter or germs of fungi) make their appearance.

If the presence of germs of fungi be doubtful, they are determined by cultivating the residue in a damp chamber for some forty-eight hours before it is *quite* evaporated to dryness. Several well-definable species of fungi have thus been produced.

The results of the examination of a number of samples, illustrated by several lithographed plates, proved that one-thousandth part of sewage or urine added to pure water so completely altered the appearance of the residue as to lead to the conclusion that still more minute quantities of the above impurities can also be detected in water by this method.

On the other hand, the residue of sewage which had been filtered through spongy iron (the process to which the author called attention at the last Meeting of the Association) exhibited throughout the characteristics of the purest water. Professor Voelcker arrived also, by chemical analysis, at the result that the sewage filtered through spongy iron was "remarkably free from organic matter, containing less organic matter than many excellent drinking-waters," thus proving that analysis and the microscopic examination come to the same conclusion.

In concluding, some residues of natural waters exhibited in the plates referred to above were explained as to their characteristics.

On the Crystallization of Metals by Electricity. By PHILIP BRAHAM.

The author of this paper gave an account of experiments with electricity under the microscope. Solutions of neutral metallic salts were placed between terminals of the base, and crystals of several metals were formed. The author hopes by the same means to obtain crystals of all.

The apparatus for regulating the quantity and intensity of the electricity was exhibited and explained.

The author then drew attention to the shape of the crystals, and suggested that, being built up of molecules, they might be typical of their elementary forms.

On the Rate of Action of Caustic Soda on a watery Solution of Chloracetic Acid at 100° C. By J. Y. BUCHANAN.

Two sets of experiments were made. In the one, the composition of the solution was expressed by the formula $C_2H_3ClO_2+NaHO+159H_2O$, in the other by $C_2H_3ClO_2+2NaHO+159H_2O$; 10 cub. centims. of the different solutions were used for every experiment. The results are given in the following Tables:—

$C_2H_3ClO_2+NaHO+159H_2O$.		$C_2H_3ClO_2+2NaHO+159H_2O$.	
Duration of heating.	Percentage, $C_2H_3ClO_2$ decomposed.	Duration of heating.	Percentage, $C_2H_3ClO_2$ decomposed.
h m		h m	
0 30	6	11 0	63
1 0	10	12 0	66
0 0	11	14 0	70
1 30	14	15 0	72
2 0	18	17 0	75
0 0	19	19 0	78
2 30	23	21 0	81
0 0	22	24 0	84
3 0	26	0 10	36
0 0	26	0 20	55
4 0	32	0 30	64
5 0	37	0 0	64
0 0	37	1 0	78
6 0	43	0 0	77
7 0	47	1 30	83
8 0	53	0 0	83
9 0	57	2 0	88
10 0	60	2 30	90

The Estimation of Sulphur in Coal and Coke. *By* F. Crace-Calvert, *F.R.S.*

The sulphur found in coal or coke often exists in two states, partly as sulphuric acid combined with lime, and partly as sulphur combined with iron. The part combined with lime, however, does not injure the quality of the iron produced when used in the manufacture of that article, as it remains in combination with the calcium, whilst the portion existing as sulphuret of iron greatly deteriorates its commercial value. To determine the quantity of sulphur in the former state, the author proposes to boil the pulverized coal or coke with a solution of carbonate of soda, which decomposes the sulphate of lime or sulphuret of calcium, and the sulphur is estimated in the solution. To show the importance of this fact in estimating the suitability of coal or coke for use in the manufacture of iron, the author gave the following percentage of sulphur as the mean of the determination in six samples of coal:—

Estimated together.	Present in washings.	Present in residue.	Difference.
1·51	·92	·64	·87

These coals by the old process would be condemned as unsuitable for use in the blast-furnace, while they are really good coals for the purpose.

In the residue from the above operation is found the sulphur combined with the iron. After attacking with oxidizing aqua regia, the author treats with carbonate of soda and heats to near the fusing-point. By this means there can be no formation of an insoluble subsulphate of iron, and the prevention of precipitation by a salt of baryta, which occurs in a liquor containing free nitric acid, is avoided.

On the Existence of Sulphur Dichloride. *By* John Dalzell *and* T. E. Thorpe.

The authors have confirmed the experiments of Hübner and Gueront, who con-

clude that, contrary to the opinion of Carius, the compound of sulphur and chlorine analogous to water does actually exist as an extremely unstable body, readily parting with a portion of its chlorine on being gently heated.

Deacon's Chlorine Process as applied to the Manufacture of Bleaching-powder on the larger Scale. By Henry Deacon.

On Sorbit. By Professor Delffs, *of Heidelberg.*

Twenty years ago M. Pelouze (Ann. de Chim. et de Phys. 3 ser. xxxv. p. 222) discovered a crystallized substance in the fruits of *Sorbus aucuparia* which he called *Sorbin.* Since that time very few chemists have paid attention to this substance, and, as far as I know, nobody in my country has succeeded in preparing it again. The principal of one of our greatest manufactories of chemical preparations, to whom I addressed myself, told me that he never found the least trace of the said substance, although he had worked up large quantities of the above-mentioned fruits for preparing malic acid; and to the same result came M. Byschl (Buchner's N. Repert. der Pharm. iii. p. 4), who asserts that there is no ready formed sorbin in the ripe berries of *Sorbus aucuparia.* In my two first attempts to procure sorbin I also failed; but during last year I succeeded, and at the same time I became aware of the reason of my previous failures. When I first tried to get sorbin, I thought it advisable to combine the preparation of malic acid with the process given by M. Pelouze for getting sorbin, and therefore I separated the former by means of acetate of lead. This is the reason, I think, which has prevented the success of myself as well as of other chemists in the preparation of sorbin.

I will not repeat the method of forming sorbin given in all manuals of chemistry; it is sufficient to say that, when I kept strictly to the prescription of M. Pelouze, I got a large quantity of beautiful crystals, a specimen of which was contained in the tube exhibited. After I had got these, I tried to obtain the malic acid from the residue, but I found that the malic acid had quite disappeared. To this I must add that the alcoholic fermentation which takes place after the juice of the berries of *Sorbus aucuparia* has been left a few days in a tepid place is more easily perceived by the formation of carbonic acid than by the smell of spirit of wine. I think it, therefore, not improbable that there is a connexion between the disappearance of the malic acid and the small produce of spirit of wine on the one side, and the formation of sorbin on the other. Suppose the malic acid, commonly called *bibasic,* and therefore apt to form a bimalate of ethyl ($=C^4H^5O+2C^4H^2O^4+HO$), assimilates two equivalents of water to this compound, you will have then the equation

$$C^4H^5O+2C^4H^2O^4+3HO=C^{12}H^{12}O^{12},$$

the right-hand side of which gives the composition of sorbin.

As pertaining to the preparation of sorbin, I have only to add that the dark sticky ley in which the crystals are formed can very easily be separated by putting both on a brick. After a few days' repose the brick has absorbed nearly all the ley, and the pale yellow-coloured crystals of sorbin, if dissolved in water and left to spontaneous evaporation, become very soon colourless.

The sorbin belongs to the same group as the mannit, quercit, inosit, dulcit, picrit, &c.; and as the last syllable is always characteristic in chemistry, its name, I think, should be changed into sorbit.

Further experiments are required to prove if the supposed genesis of sorbit is true or not; but, in any case, I am convinced that there is no sorbin *ready formed* in the fruits of *Sorbus aucuparia.*

On the Detection of Morphine by Iodic Acid. By Prof. Delffs.

Among the poisonous alkaloids which in forensic cases most frequently give occasion for chemical investigations morphine occupies the first place. For its

detection a great many tests have been proposed, most of which, however, have little interest for the forensic chemist, particularly as they depend on phenomena which may also be produced by other substances beside morphine. It is not intended here to justify this assertion by a critical examination of all the tests for morphine which are liable to the reproach mentioned; it will be sufficient to signalize one of them, the iodic acid, as an example. The well-known property of this acid, of being reduced by morphine, is certainly adapted to distinguish the latter from other alkaloids, but is altogether insufficient to establish the nature of morphine, because there are a great many other substances, partly of organic, partly of inorganic origin, which likewise reduce iodic acid. Nevertheless I have found that iodic acid, with the aid of the microscope, presents a sure means of characterizing morphine perfectly, because the reaction between this alkaloid and the above-mentioned test proceeds under such peculiar appearances that morphine cannot be mistaken for any other substance. The process to be adopted for this purpose is the following:—

After the morphine (of which the smallest particle is sufficient) is placed on a slip of glass and covered with a glass cover, as much water is added as will fill the space between the slip and the cover and extend a little beyond the margin of the latter. After the glass slip is put under the microscope and this is directed to the morphine, a particle of iodic acid is put into the water at the margin of the covering glass. In a few moments a great number of minute spherical yellow molecules, of constantly equal diameter, are seen to move in a direction from the iodic acid to the sides of the morphine, and soon form in its vicinity numerous colourless needle-shaped crystals, mostly united so as to form tufts. For the observation of this microscopic metamorphosis a magnifying-power of 300 linear would be the most suitable; when a more powerful system of lenses is employed, the difference of the focal distances of the morphine and the above-mentioned molecules and crystals readily becomes too great for the distinct observation of the whole simultaneously. Hence it is also advantageous to place under the covering glass the *thinnest* possible fragment of morphine.

I reserve for another place a more detailed communication on this subject.

Experiments on Chemical Dynamics.
By J. H. Gladstone, *F.R.S., and* Alfred Tribe, *F.C.S.*

The authors had recently communicated a paper to the Royal Society in which they investigated somewhat minutely what takes place when a plate of one metal, such as copper, is immersed in a solution of a salt of another metal, such as nitrate of silver. They had shown that, while the silver was being deposited on the copper, an actual passage of the nitric element towards the more positive metal occurs, causing the formation of a dense solution of nitrate of copper inside the crystalline deposit, and a consequent downward current, and at the same time an upward current of almost pure water from the tips of the crystals. They had shown, also, that with solutions of different strengths the chemical action in a given period (say ten minutes) is not in direct proportion to the strength; but, *cæteris paribus*, twice the strength gives three times the chemical decomposition. This augmentation had been attributed to an increased conduction of the stronger liquid. In the present paper the authors exhibited these phenomena in a dissected form, and carried the observations still further.

Instead of the silver crystals being allowed to grow from the copper into the nitrate-of-silver solution, two separate plates were taken, one of copper and the other of silver. The copper plate was immersed in nitrate of copper, and the silver plate in nitrate of silver, while the two metals were connected by a wire, and the two liquids were connected by a porous cell. Silver crystals were gradually formed upon the silver plate, while the copper was dissolved; and at the end of some hours it was found that all the silver had been removed from solution, and that the loss of the copper plate was almost exactly what might be calculated from the amount of nitrate of silver originally placed in the other cell. The actual numbers were—theoretical 0·412, actual 0·402. The copper nitrate was formed in

the cell with the copper plate, the specific gravity of the liquid having risen from 1·015 to 1·047.

A similar experiment was tried with plates of copper and zinc in sulphate of copper and sulphate of zinc respectively. The result was as before, metallic copper being deposited on the copper plate, and the sulphate of zinc rising in specific gravity from 1·123 to 1·139.

In order to determine whether the amount of silver deposited depended, not merely on the amount of the silver in solution, but also on the amount of copper salt that bridged over the intervening space, similar experiments were made in which the nitrate of silver was kept constant, but the nitrate of copper was increased by equivalent multiples. It was found that the silver deposited increased with the increase of the copper salt, being about double when the copper salt was seven times as strong, and that the effect of successive additions gradually diminished. This is in strict accordance with other experiments, showing that, when the copper plate is immersed in a mixture of the nitrates of copper and silver, the amount of silver deposited is increased, and increases with each successive addition of copper salt, though in a diminishing ratio.

That this acceleration is not produced by a copper salt only was proved by repeating the experiment with a variety of other nitrates.

The subjoined Table shows the results, and indicates, at the same time, that the increased effect does not depend simply upon the nitric element, which was present in the same quantity in all, but likewise on the nature of the salt.

Size of plate 3230 sq. millims.; volume of solution 72 cub. centims., containing 2·8 per cent. of nitrate of silver; temperature 18° C.; time 5 minutes.

Solution.	Copper dissolved.	Increase per cent.
	grm.	
Nitrate of silver	0·0703	
Ditto + 1 equiv. of nitrate of magnesium	0·1010	43·6
,, ,, ,, calcium	0·1003	42·6
,, ,, ,, sodium	0·0957	36·1
,, ,, ,, copper	0·0965	37·2
,, ,, ,, potassium	0·1047	48·9
,, ,, ,, strontium	0·1040	47·9
,, ,, ,, cadmium	0·1030	46·5
,, ,, ,, barium	0·0987	40·3
,, ,, ,, lead	0·0945	34·4

On Crystals of Silver. *By* J. H. Gladstone, *F.R.S.*

The crystalline deposit on copper or zinc immersed in silver nitrate forms a very beautiful object when viewed under the microscope. The form, colour, and general character of it depend very much on the strength of the solution; if weak, say 1 per cent., the red metal is presently covered with a growth of small crystals, which are quite black; but as the action proceeds some of these crystals grow more rapidly than others, especially at the angles of the plate, and the new growth is white. If the solution be stronger, say 3 per cent., there is no black deposit, but the white silver simulates the appearance of furze-bushes or fern-leaves of varied structure. In much stronger solutions, say 12 per cent., the crystals reminded the author of juniper-branches, and in stronger still they had rather the outward form of moss. In nearly saturated solutions the crystals of silver end in thick knobs. The crystals at first advance pretty uniformly into the liquid, but when they have considerably reduced its strength, there usually happens a stoppage of the general advance, and a special growth from one or two points, forming long feathery crystals, that sweep rapidly through the lower part of the solution. In a 1 per cent. solution these are long meandering threads, with tufts like the dendritic appearances in minerals. The crystals are peculiarly beautiful when nitrate

of copper or of potassium has been previously added to the nitrate of silver. Some other forms were described as produced under peculiar circumstances, such as long straight threads, of extreme tenuity, often changing their direction at a sharp angle.

Note on Fibrin. *By* Dr. JOHN GOODMAN.

The author having read a paper on the above subject at the Meeting of the Association in Liverpool last year, has been since that period constantly engaged in a long series of experiments establishing the truth of the statements there set forth. The following is an epitome of the results obtained. The experiments were performed under the microscope:—

1. Albumen immersed for some short time in cold water loses its characters as albumen, and becomes transformed into a substance which the author asserts exactly resembles blood-fibrin under the microscope.
2. This substance exhibits intense attractive powers.
3. It decomposes peroxide of hydrogen with effervescence. According to the author's views, all these experiments showed that water is the primary source of this change, and that until albumen is in some way subjected to the influence of water, oxygen can exert no influence in producing this change.
4. The rapidity or intensity of the transformation was not increased by raising the temperature of the water.
5. Ovalbumen does not *per se* become transformed into fibrin by the voltaic currents, only to such an extent as its water of fluidity is available for this purpose.
6. But when diluted with water the entire mass of albumen submitted to the current was rapidly transformed into fibrin.
7. When this substance was submitted to potash it dissolved in three minutes, whilst blood-fibrin required twelve hours and ovalbumen twenty-four hours for solution.
8. In strong hydrochloric acid both this substance and blood-fibrin dissolved in twenty-four hours, whilst ovalbumen was not completely dissolved in sixteen days.
9. In all acid solutions of this substance, and of blood-fibrin precipitated by alkalies, and of alkaline solutions precipitated by acids, the author asserts that he invariably finds fibrinous rods and formations perfectly identical in their appearance one with the other, and without any coagulum peculiar to albuminous precipitations; whilst on the other hand in similar solutions of albumen similarly precipitated, he finds as invariably a dense flocculent coagulum, without the presence of fibrinous rods or other formations. Alkaline solutions, moreover, of albumen precipitated by acetic acid gave always a dense white and flocculent coagulum, and those precipitated by nitric acid gave a lemon-yellow precipitate, whilst neither white nor lemon-yellow coagula occurred in similar precipitations from like solutions of fibrin thus produced as blood-fibrin. The author maintains that these experiments show that the substance thus produced by the agency of water is genuine fibrin.

Preliminary Notice on a New Method of Testing Samples of Wood-Naphtha. *By* WILLIAM HARKNESS, *F.R.M.S.*

The detection of wood-naphtha, when present in alcohol, is now comparatively easy, but the converse problem, viz. the detection of alcohol in wood-naphtha, does not seem to have occupied the attention of chemists generally.

Methylated spirit, which is cheaper than wood-naphtha, is the only adulterant likely to be used, and any simple mode of determining its presence must be of some value to the chemist. One of the most common methods of examining a sample of naphtha is to ascertain its boiling-point; but this is not reliable, as different samples, even of the same specific gravity, may boil at different temperatures, varying from 138° F. to 156° F., and yet be free from ethylic alcohol.

The following method of testing samples was discovered by the author whilst

engaged in the preparation of oxalate of methyl. It was noticed that different samples of naphtha gave different quantities of this crystalline body. Further investigations showed that the presence even of a small quantity of methylated spirit or alcohol in the wood-naphtha from which the oxalate was prepared, altered in the most striking manner the temperature at which solidification took place. Thus, oxalate of methyl prepared from pure wood-naphtha is always solid at a temperature exceeding 100° F. This has been confirmed by experiments on all kinds of naphtha, English and foreign.

In samples containing methylated spirit or alcohol, crystallization always takes place at a temperature less than 100° F., such temperature depending on the percentage of alcohol present. The following are the averages of many experiments:—

Per cent. of alcohol in naphtha.	Oxalate of methyl solid at or about.
0	104° Fahr.
5	95
10	86
15	76
20	64
30	49
40	27
50	9

The test is easily applied. Distil at a moderate heat 1 oz. of the suspected spirit, 7 drs. oxalic acid, and 1 oz. sulphuric acid; collect the crystals, if any, in a small beaker, and heat until the crystals melt, then with a thermometer watch the temperature at which crystallization again takes place.

One precaution is necessary: the sample examined, if not miscible with water, must be rendered so by filtration through charcoal previous to testing.

A Method of Preserving Food by Muriatic Acid.
By the Rev. H. Highton, *M.A.*

As the great objection to preserving articles of food by chemical compounds is that it imparts a flavour to them more or less unpleasant, it occurred to the author to try whether they could not be preserved in the first instance by muriatic acid, and then before use be deprived of their acidity by means of soda or its carbonates. The author tried many experiments, and found that in many cases the plan might be employed with very good results, the muriatic acid not affecting the most delicate flavours, but leaving the article just as it was before, with only a slight not objectionable taste of common salt. There are two principal ways of effecting the object:—

1. To dip the meat, fish, or other substance at intervals, if necessary, and expose it freely to the air to dry. During this process of drying the coating of muriatic acid prevented the approach of decomposition. Meat and fish thus prepared remained perfectly sweet for many months. The only thing necessary before using them was to steep them in a very dilute solution of carbonate of soda till any slight traces of the acid were neutralized.

2. The other plan is to enclose the substance in a close vessel with a small quantity of muriatic acid, so as to prevent evaporation. A very small quantity of muriatic acid seems to be sufficient to destroy the germs of decomposition—a quantity which, when ultimately neutralized by soda, gives a scarcely perceptible flavour of salt. A too large quantity of muriatic acid tends itself to decompose the substance submitted to its action.

One application of the plan was described. If meat be cut up small and steeped in weak muriatic acid, and when it is thoroughly penetrated boiled in a very dilute solution of carbonate of soda, carbonic acid is evolved in the pores of the meat, and splits it up into such minute fragments as to produce virtually a solution of the meat.

On the Aluminous Iron-ores of Co. Antrim. *By* Dr. J. Sinclair Holden, *of Larne.*

These ores have only been discovered within the last few years, and exhibit a seam both extensive and rich. It lies continuously for about seventy miles along the coast and mountain-glens of Antrim, being nearly horizontally interspread throughout the basaltic rocks which form the floor of the county, and at an average height of 300 feet above the white limestone.

The elevation above sea-level varies considerably, as among the highest mountains it is found at a height of over 1000 feet, from which it gradually falls north and south as low as 200 feet. The general dip of the beds is south-west.

Dr. Holden gave analyses of the ore, and adds that it is not analogous to any known iron deposit in England, and that basaltic rocks, though containing some iron in their composition, are not generally associated with large deposits of iron-ore. The ferruginous stratum consists of three qualities of ore, which, in descending order, are :—

	ft.	Average Metallic Iron per cent.
Pisolite	2	50
Bole	8	20
Lithomarge	30	12
Total thickness	40	

These graduate into each other. The upper bed, or pisolite, is the richest in iron, and working quantities can be mined containing from 30 to 50 per cent. of metallic iron.

Large quantities of this ore have now been raised and shipped to England, where it has already made a reputation for itself, in facilitating the production of pure iron from the siliceous hæmatites. The entire absence of phosphorus and sulphur, and the presence of a large percentage of alumina, add much to its value, both as an iron-ore and a flux.

When intermixed with the siliceous ores in the smelting-furnace, the effect is to soften the slag, producing a "loose load," which allows the metal to pass through easily, forming a pure "pig," and, from a given quantity of the mixed ores, determining a higher percentage of metallic iron than could be otherwise obtained.

It is chiefly used in Lancashire, Cumberland, and South Wales, and is becoming a necessity where good steel-iron is demanded. To show that an extensive source of industry has already been developed, it may be stated that upwards of 50,000 tons were exported last year, and the quantity will be much greater this year.

The discovery of this ore has had the effect of stimulating mineral research in the adjoining counties, and Dr. Holden states not in vain, as samples of a good siliceous hæmatite have been shown him, and only wait exploration where they were discovered. If found in quantity, no better outlay of capital could be invested than in the erection of smelting-furnaces on the Antrim coast.

As suggested by the President of the Section, there could be utilized in the local smelting of the ores the large quantity of peat available in the north of Ireland.

Localities of Dioptase. *By* Professor N. Story Maskelyne, *F.R.S.*

Dioptase has hitherto only been known as a product of the copper-mine at Altyn Tubeh, in the Kirghese steppes of Tartary, if we except certain reputed localities in Germany; it has been recently met with among old specimens that have been traced to localities in Chili.

One of these was among the specimens preserved in drawers at the British Museum, which have lately been under careful examination with a view to their identification, and another similar specimen was obtained some years since by W. G. Lettsom, Esq., the well-known mineralogist, from a dealer at Vienna.

The crystals on both are minute but distinct, and are those of dioptase. The

gangue is a compact micaceous hæmatite; the locality, traced to an old sale catalogue of Heuland's, is the Rosario Mine, Chili.

It is singular that other specimens of the same mineral should have been found among the specimens preserved in the British Museum. One of these is associated with chrysocolla and ochre on a quartzose veinstone, another occurs as a thin crust on a schorlaceous rock, both being from a Chilian locality. A specimen recently obtained is associated with quartz and eisenkiesel, and is from the Mina del Limbo, Del Salado, Copiapo, Chili.

On Andrewsite. *By* Professor N. STORY MASKELYNE, *F.R.S.*

A somewhat well-marked group of minerals would seem to justify the designation of the Dufrenite group, by reason of their having, as a common constituent (or being capable of being so represented), a compound of which the formula is $R_2P_2O_8 + R_2H_6O_6$; R being Fe in the case of Dufrenite.

Dufrenite being $Fe_2P_2O_8 + Fe_2H_6O_6$, or, in Berzelian symbols, $\overset{\cdots}{\overline{\mathrm{Fe}}}\,\overset{:\cdot:}{\overline{\mathrm{P}}}, \overset{\cdots}{\overline{\mathrm{Fe}}}\,\dot{\overline{\mathrm{H}}}_3$.

Peganite is $\overset{\cdots}{\overline{\mathrm{Al}}}\,\overset{:\cdot:}{\overline{\mathrm{P}}}, \overset{\cdots}{\overline{\mathrm{Al}}}\,\dot{\overline{\mathrm{H}}}_3 + 3\dot{\overline{\mathrm{H}}}$.

Fischerite is $\overset{\cdots}{\overline{\mathrm{Al}}}\,\overset{:\cdot:}{\overline{\mathrm{P}}}, \overset{\cdots}{\overline{\mathrm{Al}}}\,\dot{\overline{\mathrm{H}}}_3 + 5\dot{\overline{\mathrm{H}}}$.

Cacoxene is $\overset{\cdots}{\overline{\mathrm{Fe}}}\,\overset{:\cdot:}{\overline{\mathrm{P}}}, \overset{\cdots}{\overline{\mathrm{Fe}}}\,\dot{\overline{\mathrm{H}}}_3 + 9\dot{\overline{\mathrm{H}}}$.

Wavellite is $2\overset{\cdots}{\overline{\mathrm{Al}}}\,\overset{:\cdot:}{\overline{\mathrm{P}}}, \overset{\cdots}{\overline{\mathrm{Al}}}\,\dot{\overline{\mathrm{H}}}_3 + 9\dot{\overline{\mathrm{H}}}$.

A mineral recently found in Cornwall, and sent to the British Museum by Mr. Talling, may perhaps be referred to this group. It has been analyzed in the Museum Laboratory, and Professor Maskelyne named it Andrewsite, in honour of the distinguished President of the Chemical Section of the British Association, Dr. Andrews, of Belfast.

Andrewsite occurs in occasional association with a bright green mineral in brilliant minute crystals, presenting a strongly marked resemblance to those of Dufrenite. This green mineral not having been as yet, from the small amount obtained of it, submitted to an analysis, is only provisionally termed Dufrenite.

The Andrewsite which it sometimes thus accompanies presents itself in globular forms or in disks with a radiate structure, and in habit curiously resembles Wavellite. Its colour is a slightly bluish green; its surface is generally formed of a very thin layer of the mineral provisionally termed Dufrenite, crystals of which occasionally stand out of the globules.

The interior of the globules is sometimes homogeneous, and consists of radiating crystalline fibres; oftener one perceives an almost sudden transition from an outer shell of some thickness, which consists of Andrewsite, into an inner core, formed of a brown mineral.

Seen under the microscope, the two minerals appear to a certain degree to interpenetrate each other, so that the selection of material for analysis is a work of much caution.

The spherules usually stand on the projections of a quartzose veinstone, protruding into a hollow, and covered with a mass of limonite, sometimes carrying a drusy crust of Göthite, and studded occasionally with a few brilliant little crystals of cuprite. The spherules are met with in one or two cases on cuprite formed round a nucleus of native copper. Andrewsite, in fact, contains copper, four analyses of separate specimens giving the percentages of 10·651, 10·702, 10·917, and 11·002.

The analyses of Andrewsite have proved sufficiently concordant to justify the formula

$$3\{Fe_2P_2O_8 + Fe_2H_6O_6\} + CuP_2O_8,$$

$$\text{or } 3\{\overset{\cdots}{\overline{\mathrm{Fe}}}\,\overset{:\cdot:}{\overline{\mathrm{P}}}, \overset{\cdots}{\overline{\mathrm{Fe}}}\,\dot{\overline{\mathrm{H}}}_3\} + \dot{\mathrm{C}}\mathrm{u}_3\,\overset{:\cdot:}{\overline{\mathrm{P}}},$$

in which, however, a portion of the ferric phosphate is replaced by ferrous phosphate, as in Vivianite is frequently the case with the two phosphates.

The parallelism of Chenevixite ($Cu_3 As_2 O_8+Fe_2 H_6 O_6$) with a portion of the above formula is worthy of attention, and may justify the formula being written as

$$2\{Fe_2 P_2 O_8+Fe_2 H_6 O_6\}+Cu_3 P_2 O_8+Fe_2 H_6 O_6+Fe_3 P_2 O_8.$$

A larger supply of the mineral will no doubt soon be forthcoming, when the formula may be fixed on the foundation of more certain analyses. The specific gravity of this mineral is 3·475, that of Dufrenite being (from Siegen) 3·2 to 3·4.

The chalkosiderite of Ullmann, the name by which, nearly sixty years ago, he designated a thin crystalline coating overlying the radiated variety of the Grüneisenstein (Dufrenite) of the Hollerter Zug, Sayn, Westphalia, does not seem to have been analyzed by him. He states that it contains copper; but the subsequent analyses of Grüneisenstein do not appear to confirm this statement; indeed it appears more nearly to resemble the green crystallized mineral which has in this note been provisionally described as Dufrenite.

On Ozonometry. *By* T. Moffat, *M.D., F.G.S.*

The author stated that ozone test-papers did not become permanently coloured in the neighbourhood of cesspools, and that the brown colour, when formed, is removed by the products of putrefaction. He also stated that light, the humidity of the atmosphere, and direction of the wind influence the colouring of the test-paper. Moisture with heat accelerates the chemical action, while a strong wind causes a greater amount of ozone to impinge upon the test-paper in a given time. To counteract the effect of these, he recommends that the test-paper be placed as far as possible from cesspools, and that it be kept in a box. He next described a tube-ozonometer which he had in use, and gave results obtained by an aspirator ozonometer, and concluded by stating that the results obtained by the latter instrument were not satisfactory.

On the Photographic Post. *By the* Abbé Moigno.

On an Antimony-ore from New Zealand. *By* Pattison Muir.

Note on Regianic Acid. *By* Dr. T. L. Phipson, *F.C.S.*

Regianic acid is one of several new substances which I have obtained at various times during the last few years from the fruit of *Juglans regia* and another species of walnut. The green husk of the walnut cedes to benzol a yellowish substance, which crystallizes, apparently in very elongated octahedra or feather-like groups of prisms. This substance, which I term *regianine*, is easily decomposed, and when treated with alkalies or ammonia, yields splendid red-purple solutions, whence acids precipitate a brown flocculent substance (impure regianic acid). The latter, redissolved in a weak solution of soda, precipitated again with hydrochloric acid, and washed with boiling water, forms a jet-black amorphous powder of great density, which is pure regianic acid. It yields to analysis the composition

$$C^6 H^6 O^7,$$

and forms a brown lead-salt, PbO, $C^6 H^6 O^7$, also a jet-black silver-salt, very similar in appearance to the acid itself, and with lime a beautiful pink-coloured salt, which is precipitated by boiling its solutions with a little ammonia.

Regianic acid is insoluble in water, but dissolves in alkalies with a beautiful red-purple tint, that has no particular action upon the spectrum. It appears to be derived from regianine by oxidation, for I extracted all the oxygen from a volume of air by placing in it a little regianine and soda.

Note on the Action of Aldehyde on the two Primary Ureas. *By* Dr. J. Emerson Reynolds.

The action of the dicarbon aldehyde of the fatty series, $C_2 H_4 O$, on certain deri-

vatives of ammonia has of late been studied with considerable care, and most interesting results arrived at in the course of the investigation. We have been long familiar with the reactions of aldehyde with aniline, described by Schiff, who has shown that the dyad group, C_2H_4'', or ethyliden, as it is often called, can replace successively two distinct proportions of hydrogen in the double molecule of aniline, water being eliminated according to the equations:—

$$2(C_6H_5, NH_2)+C_2H_4''O= \left\{\begin{matrix} C_6H_5, NC_2H_4 \\ C_6H_5, NH_2 \end{matrix}\right\} +H_2O. \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$2(C_6H_5, NH_2)+2(C_2H_4''O)= \left\{\begin{matrix} C_6H_5NC_2H_4'' \\ C_6H_5NC_2H_4'' \end{matrix}\right\} +2H_2O. \quad \ldots\ldots \quad (2)$$

We are also acquainted with analogous reactions which have been obtained with amides and aldehydes of the aromatic series; it therefore appeared to be a matter of some interest to examine the action of aldehyde on another class of ammonia derivatives, the group of so-called *ureas*. Of these, there are at least two primary bodies—one the well-known product of the animal organism, or Wöhler's beautiful artificial urea; and the other, the sulpho-urea, which was discovered a few years ago by the author.

It is unnecessary now to discuss the question of the identity or otherwise of Wöhler's and the normal urea; it is sufficient here to mention that all these experiments have been made on Wöhler's urea and on the analogous sulphur compound.

It will be convenient for the present to regard the two ureas just referred to as ammonia derivatives respectively of carbonic (according to Dr. Kolbe carbamic) and sulpho-carbonic acids; thus—

Wöhler's urea .. .. .. $CO''\left\{\begin{matrix} NH_2 \\ NH_2 \end{matrix}\right.$,

Sulpho-urea .. .. .. $CS''\left\{\begin{matrix} NH_2 \\ NH_2 \end{matrix}\right.$,

the author's object being to attempt the partial or complete replacement of hydrogen in each urea by the ethyliden group, according to the equation

$$CS\left\{\begin{matrix} NH_2 \\ NH_2 \end{matrix}\right\} + C_2H_4''O = CS\left\{\begin{matrix} NC_2H_4'' \\ NH_2 \end{matrix}\right\} + H_2O.$$

The chief results arrived at in the course of the inquiry are the following:—

Action of Aldehyde on the Sulpho-Urea.

The first experiments were made with the sulpho-urea. A quantity of the pure compound was dissolved to saturation in nearly anhydrous aldehyde. The hot saturated solution was digested in a hermetically sealed flask, at a temperature of 100° C., for two hours. The solution was then allowed to cool. No urea-crystals were deposited. After two days' standing, however, a number of minute, spherical, subcrystalline masses were found to have attached themselves to the sides of the flask, and these gradually increased in quantity, until a considerable amount had been obtained. The clear liquid gave a copious white precipitate with water and with alcohol. The deposited body was carefully washed with cold alcohol, in which it is very slightly soluble, and then purified by solution in a large volume of boiling anhydrous alcohol, from which the new body separates out to a large extent on cooling, as a somewhat starch-like granular substance, seen under the microscope to be made up of extremely minute crystals. The analysis of the body gave numbers agreeing well with the formula

$$CS''\left\{\begin{matrix} NC_2H_4'' \\ NH_2, \end{matrix}\right.$$

and is therefore derived from the urea by the replacement of half the hydrogen by ethyliden.

The new body is but slightly soluble in ether, rather more so in cold alcohol, but its solubility in boiling alcohol is much greater. In consequence of its relations to these solvents, the substance can be easily purified. It is but very slightly,

if at all, truly soluble in cold water; but when digested at 100° C. with water, solution is obtained (but solution in consequence of decomposition), aldehyde being produced, and the urea separated with some ammonium sulphocyanate. The essential reaction is probably correctly represented by the equation

$$CS'' \left\{ \begin{matrix} NC_2H_4 \\ NH_2 \end{matrix} \right\} + H_2O = CS'' \left\{ \begin{matrix} NH_2 \\ NH_2 \end{matrix} \right\} + C_2H_4''O,$$

or the converse of that according to which the *ethyliden sulpho-urea* is formed; dilute acids and alkalies act in the same way.

From the alcoholic solution the author obtained a platinum salt and a gold compound.

Action of Aldehyde on Wöhler's Urea.

The urea was dissolved nearly to saturation in aldehyde, and the solution digested in a sealed flask for two hours at 100° C. When cool, the flask was opened, and the contents poured into a suitable vessel, and the aldehyde slowly evaporated. No crystals of the urea were deposited, but a transparent pasty mass remained when the solvent had been almost wholly driven off. After standing for twenty-four hours, the residue was found to be white and friable. The mass was powdered, and digested in the cold with nearly anhydrous alcohol, in which it is very slightly soluble at ordinary temperature, washed with the same liquid, and then boiled with alcohol. The filtered solution so obtained deposits, on rapid cooling, a considerable quantity of a flocculent body, seen under the microscope to be wholly made up of minute and considerably modified monoclinic crystals. Analysis gave the formula

$$CO'' \left\{ \begin{matrix} NC_2H_4'' \\ NH_2 \end{matrix} \right.$$

for this body. A platinum compound has been obtained, but no gold salt.

The new substance is easily decomposed by digestion with water into aldehyde and the products of decomposition of the urea. The first stage of the reaction may, no doubt, be represented by the equation

$$CO \left\{ \begin{matrix} NC_2H_4'' \\ NH_2 \end{matrix} \right\} + H_2O = CO \left\{ \begin{matrix} NH_2 \\ NH_2 \end{matrix} \right\} + C_2H_4''O.$$

Having succeeded in replacing half the hydrogen in each of these ureas, directly and by a very simple reaction, the author endeavoured to go a step further, and substitute a hydrocarbon group for the residual hydrogen within the molecule. All attempts in this direction have hitherto been fruitless.

In view of the facts above stated and others well known, proving that half the hydrogen only is capable of replacement, and that each atom of nitrogen within the molecule of the urea is somewhat differently engaged, we are clearly warranted in slightly modifying the rational formula of each urea, in order to bring it into more complete harmony with the facts. The extent of the alteration is apparent when we write the formulæ of the ethyliden ureas referred to in this note, thus:—

$$\text{Ethyliden urea} \left\{ \begin{matrix} NC_2H_4 \\ COH \\ NH. \end{matrix} \right.$$

$$\text{Ethyliden sulpho-urea} \left\{ \begin{matrix} NC_2H_4 \\ CSH \\ NH. \end{matrix} \right.$$

On the Analysis of a singular Deposit from Well-water.
By Dr. J. Emerson Reynolds.

On the Chemical Constitution of Glycolic Alcohol and its Heterologues, as viewed in the new light of the Typo-nucleus Theory. *By* Otto Richter, *Ph.D.*

The chemical constitution of glycolic alcohol and its heterologues may be ade-

quately expressed by means of the following table of rational formulæ *, where the non-essential constituents are separated from the essential constituents by a horizontal line :—

$H_{12}C_8O_8$ Glycolic alcohol.	$\dfrac{H_2O_2. \qquad H_2O_2.}{2C_2;\ H_2O_2\text{⁏}\ 2H_2C_2;\ H_2O_2}$
$H_8C_8O_8$ Deglycolic alcohol.	$\dfrac{H_2O_2. \qquad H_2O_2.}{2C_2;\ H_2O_2\text{⁏}\ 2C_2;\ H_2O_2}$
$H_8C_8O_8$ Glycolite of water.	$\dfrac{H_2O_2. \qquad H_2O_2.}{2C_2;\ H_2O_2\text{⁏}\ 2H;\ 2C_2O}$
$H_8C_8O_{12}$ Glycolate of water.	$\dfrac{H_2O_2. \qquad H_2O_2.}{2C_2;\ H_2O_2\text{⁏}\ 2H;\ 2C_2O_3}$
$H_8C_8O_{16}$ Oxyglycolate of water.	$\dfrac{H_2O_2. \qquad H_2O_2.}{2C_2;\ H_2O_2\text{⁏}\ 2H;\ 2C_2O_5}$

So far as the author knows, the glycolic alcohol, which is the parent molecule of this family group, has not yet been obtained in a state of isolation. The ethylen-glycol might at first sight be taken for the missing alcohol, more particularly when we couple the decidedly biatomic character of their respective molecules with the other, and even more significant fact, that the whole of the glycolic heterologues may be produced by the simple oxidation of the ethylen-glycol. Nevertheless, and notwithstanding these striking points of resemblance, the author is inclined to believe that these two alcohols are only isomeric; and he grounds this belief upon the occurrence of a certain class of chemical compounds, among which the so-called diethyl-acetal is the most conspicuous and best investigated member. This diethyl-acetal is strictly isomeric with the diethyl-ether of the ethylen-glycol, and it is no doubt the missing glycolic alcohol to which we are indebted for this curious and instructive case of isomerism. A cursory examination and comparison of the subjoined rational formulæ will suffice in order to prove the correctness of this view.

$H_{12}C_8O_8$ Ethylen-glycol.	$\dfrac{H_2O_2. \qquad H_2O_2.}{2H_2C_2;\ H_2O_2 \smile 2C_2;\ H_2O_2}$
$H_{12}C_8O_8$ Glycolic alcohol.	$\dfrac{H_2O_2. \qquad H_2O_2.}{2C_2;\ H_2O_2\text{⁏}\ 2H_2C_2;\ H_2O_2}$
$H_{28}C_{24}O_8$ Diethyl-ether of ethylen-glycol.	$\dfrac{2H_4C_4;\ H_2O_2. \qquad 2H_4C_4;\ H_2O_2.}{2H_2C_2;\ H_2O_2 \smile 2C_2;\ H_2O_2}$
$H_{28}C_{24}O_8$ Diethyl-acetal.	$\dfrac{2H_4C_4;\ H_2O_2. \qquad 2H_4C_4;\ H_2O_2.}{2C_2;\ H_2O_2\text{⁏}\ 2H_2C_2;\ H_2O_2}$

Ethylen-glycol differs from glycolic alcohol in two essential points :—First, in the former compound the two alcoholic constituents are represented as playing the coordinate part of principal alcoholic bases, while in the latter compound one of these alcoholic bases is represented as playing the subordinate part of adjunct to the other base. Secondly, the relative positions which the two alcoholic constituents occupy in ethylen-glycol are exactly reversed in the glycolic alcohol. A mere glance at the two formulæ which express the chemical constitution of the isomeric ether derivatives will enable the reader to complete the analysis of these hitherto obscure and unintelligible cases of isomerism. To the second member in the family of glycolic heterologues, which is likewise very little known, the author has applied the term "deglycolic alcohol," in order to record the fact that it is produced from the primary alcohol by the simple abstraction of two molecules of hydrogen from the methylen adjunct of the principal water-base. This secondary alcohol, like the majority of the alcohols which occupy the second place in the

* The following are some of the typical symbols of molecular grouping used in these formulæ: a dot connects the base with its acid, a semicolon the hydrocarbon adjunct with its principal, an inverted semicolon the halogen (acid, base, or salt) adjunct with its principal, and a concave curve two principal bases with one another—

$$H_2=2;\ C_2=12;\ O_2=16.$$

family group of the heterologues of the fatty alcohols, seems, from its want of stability, very prone to merge into the isomeric and far more permanent modification of the glycolite of water. In this remarkable metamorphosis the double carbon adjunct of the principal water-base becomes first of all converted into an acid twin carbon-nucleus, which reunites under this new form with the old water-base, whereupon, under the combined influence of base and acid, the remaining water-molecule becomes decomposed, so as to surrender its oxygen to the envelope of the acid twin carbon-nucleus, while the hydrogen connects itself with the same nucleus under the typical form of a hydrocarbon adjunct. It is worthy of note that in this singular and characteristic rearrangement of the constituent elements the organic molecule has, without loss of substance and without loss of saturating capacity, passed at one bound from the category of a true and genuine alcohol into the category of a true and genuine water-salt. As regards the two remaining heterologues of glycolate of water and oxyglycolate of water, you cannot but see that their formation is due to the successive absorption of two molecules of oxygen by the envelope of the glycolous acid constituent, and that they differ from each other in this respect only, that the former contains for its principal constituent formate of water, while the latter contains instead of it oxyformate of water. This oxyformate is a highly interesting isomeric modification of the neutral carbonate of water, which, on account of its excessive want of stability, cannot be obtained in a state of isolation. The compound before us differs from the isomeric neutral carbonate in being decidedly monobasic, while the latter is as decidedly bibasic. The cause of this apparent anomaly becomes now fully revealed; for it is plain that one of the two hydrogen-molecules, which in the ordinary carbonate of water are both of them readily displaceable by metals, has assumed the hydrocarbon form of grouping, in consequence of which it will cease to play the part of a basic nucleus; and although it may become eliminated or exchanged in obedience to other modes of substitution, it is certain that the ordinary process of double decomposition has no control over it.

The Molecular arrangement of the Alloy of Silver and Copper employed for the British Silver Coinage. By WILLIAM CHANDLER ROBERTS, *Chemist of the Mint.*

Experiments have demonstrated that when a molten alloy of silver and copper is allowed to cool, the composition of the resulting metal is not uniform, the cooling being attended with a remarkable molecular rearrangement, in virtue of which certain constituents of the molten alloy become segregated from the mass, the homogeneous character of which is thereby destroyed.

Thus, to take an extreme case, an alloy containing 77·33 per cent. of silver and 22·67 per cent. of copper was cast in a cubical mould of 42 millimetres. A portion cut from the centre of the mass gave on assay 78·318 per cent. of silver, while a portion cut from one of the angles was found to contain only 77·015 per cent. of silver, showing a difference of 13·03 millièmes.

Levol proved that the alloy containing 71·89 per cent. of silver is homogeneous, and in all alloys containing more silver than this amount the centre of the solidified mass is richer than the exterior; on the other hand, in alloys of fineness lower than 71·89, the centre contains less silver than the external portions.

The alloy employed for the British silver coinage contains 925 parts of silver and 75 parts of copper in 1000 parts of alloy. The metals are melted together and cast into bars 18 inches long and 1 inch thick; these bars are subsequently rolled into strips or ribands, and from these ribands the disks of metal to form the coins are cut.

Experiments conducted in the most careful manner proved that the centre of the riband contained more silver by two parts in the thousand than the external edges. The increase in richness from one edge of the riband to the centre, and the corresponding decrease in richness from the centre to the opposite edge, was extremely regular, as was shown by the curve or graphic representation of the results by which the paper was illustrated.

On the Retention of Organic Nitrogen by Charcoal. By E. C. C. Stanford.

Improvements in Chlorimetry.
By John Smyth, *Jun., A.M., M.I.C.E.I., F.M.S.*

The author showed that the use of the milky solution of bleaching-powder in chlorimetry is unsatisfactory, and was therefore glad to discover a method of securing a clear solution containing all the chlorine by dissolving the sample in an alkaline solution. This is conveniently done by adding, say, 10 grammes of bleaching-powder to 20 grammes of soda-crystals ($Na_2CO_3+10H_2O$), filtering out the precipitated carbonate of lime, which is known to be washed when it no longer discharges the colour of dilute sulphate of indigo, and making up the filtrate by water to one litre of fluid. It is a clear colourless liquid of the sp. gr. 1·007, but if made of sp. gr. 1·233 it is slightly greenish, having a pleasant oily feeling between the fingers, contrasting favourably with the roughness of the decanted solution of the bleaching-powder, with which it gives a precipitate. Most satisfactory results are obtained from it by all the chlorimetrical methods; and it has the additional advantage of showing the amount of lime in the sample, a solution of known strength of carbonate of soda being added until a precipitate is no longer formed. It is manufactured and used in the north of Ireland for bleaching fine linens; and from the ease and accuracy with which the percentage of chlorine was obtained, the author was led to investigate the feasibility of converting bleaching-powder into it for chlorimetrical purposes, and obtained the above results.

Contributions to the History of the Phosphorus Chlorides.
By T. E. Thorpe, *Ph.D., F.R.S.E.*

I. *On the Reduction of Phosphoryl Trichloride.*

The author has attempted, but without success, to prepare the phosphorus chlorides corresponding to the oxychlorides of vanadium discovered by Roscoe. He found that when phosphorus oxychloride was heated with metallic zinc in a sealed tube to a temperature above the boiling-point of mercury, the phosphorus trichloride ($P\,Cl_3$) was produced. It appears, therefore, that the action of zinc at a high temperature on phosphoryl trichloride is sensibly different from the action of this metal on the corresponding vanadium compound; in the former case the reaction is attended with abstraction of oxygen, in the latter with abstraction of chlorine.

II. *On the Preparation of Phosphorus Sulphochloride.*

The author found that perfectly pure phosphorus sulphochloride may be easily prepared by a reaction analogous to that by which phosphoryl trichloride has long been obtained; that is, by simply substituting P_2S_5 for P_2O_5 according to the following reaction, $P_2S_5+3\,P\,Cl_5=5\,PS\,Cl_3$.

The materials mixed in this proportion were heated in a sealed tube to about 150° C.; in a few minutes combination was quietly effected, and the entire contents of the tube were transformed into colourless phosphorus sulphochloride, a mobile liquid boiling constantly at 126° at 770 millims barom. Its vapour is extremely irritating, but when diluted with air it has an aromatic odour, reminding one of that of the raspberry.

On the Dissociation of Molecules by Heat.
By C. R. C. Tichborne, *F.C.S., M.R.I.A.*

The term dissociation is applied by the author to specify a certain class of phenomena somewhat distinct from ordinary decomposition. This latter term is generally applied to any case of molecular change which has been consummated, whilst dissociation is used to convey a passive but present phenomenon. If this latter is carried far enough, it ultimately results in a rupture, and thus the phenomena of decomposition and dissociation are so intimately connected, that they can hardly be investigated alone.

Compound molecules exist in the solid, liquid, and gaseous condition, providing that the temperature necessary to convert them into these physical modifications is not above the temperature at which their components are dissociated. Thus we can easily conceive that a substance A may be of sufficient structural stability to pass through all the increasing vibratory action of heat without dissociation of its component molecules, until it has passed through the solid, liquid, and far into the vaporous condition; whilst a substance B has what the author calls a thermanalytic point, or the point where the equilibrium is broken. If it lies below 100° C., we have dissociation in the liquid condition among compounds soluble in water.

A well-known natural group of bases had been studied as regards these phenomena, viz. the trioxides, alumina, chromic and ferric oxides, and it has been found that all the compound molecules of these bases were more or less dissociated on heating their solutions.

The ferric compounds are the most easily affected. The solutions of these compounds, if pure, are almost colourless; the usual slight tinge being in most cases produced by the basic action of the water. By the cautious addition of dilute acid, almost colourless solutions will be procured. On the application of heat this solution becomes gradually darker and darker, until it becomes a dark reddish-brown fluid. If the water bears any considerable proportion to the salt, a basic precipitate falls before it has reached the boiling-point. The relative amount of the water is of the utmost importance in these phenomena, because its basic action lowers the thermanalytic point. The result of the dissociative influence of heat when a precipitate is not produced, is the repartitioning of the elements by which a basic and an acid salt are produced in the same fluid simultaneously. If these experiments are carried on under pressure, or in the presence of a great excess of water, the dissociative influence is so great from the increased range of temperature, that anhydrous oxide of iron can be produced in the presence of water.

The compounds of chromium are capable of dissociation in a similar manner, and the change of colour produced by heat upon these solutions is due to basic condition, and not to the state of hydration of the salt as generally stated.

The aluminic molecules obey exactly the same rule; but as the thermanalytic point is much higher, and as there is no chromatic change to mark the dissociative influence of heat, it is difficult to discern the phenomenon. Under the influence of solutions boiling at an increased pressure of 11 or 12 atmospheres alumina was procured. The same results may be obtained by increasing the basic condition of the solution by a large volume of water. As the pressure raises the boiling-point of the water until we reach the thermanalytic point of the molecule, so the basic action of the water upon the stylous group lowers the thermanalytic point until we get it within the range of 100° C. If 500,000 to 600,000 times the weight of water is used to the amount of salt, a precipitate is produced at 100° C. This precipitate is best seen by passing a beam of electric light through the flask. Most of the precipitates may be observed by the eye, but not all; they redissolve on cooling.

On the behaviour of Supersaturated Saline Solutions when exposed to the open air. By Charles Tomlinson, *F.R.S.*

It is known that when a vessel containing a supersaturated saline solution is opened in a room, it immediately crystallizes provided the temperature be not too high. Mr. Tomlinson shows that supersaturated solutions of Glauber's salt (and also of Epsom salts and of alum) may be exposed to the open air of the country for many hours, and even be taken out of the flasks in clean metal spoons, without crystallizing. From a large number of experiments conducted under various conditions, the following conclusions are drawn:—

1. That a highly supersaturated solution of sodic sulphate may be exposed to the open air of the country in an uncovered flask, and in cloudy weather, for from twelve to twenty hours, without any formation of the ordinary ten-watered crystals,

2. That if the temperature fall to 40° Fahr. and under, the modified seven-watered salt is formed at the bottom of the solution just as in covered vessels.

3. That if the exposed solution suddenly crystallize into a compact mass of needles, a nucleus may always be found in the form of an insect, a speck of soot, a black point of carbon, &c.

4. That if during the exposure rain come on, the solution generally crystallizes suddenly in consequence of an active nucleus being brought down; but if the flask be put out during heavy rain, when we may suppose all the solid nuclei to be brought down, the rain-drops, now quite clean, fall into the solution without any nuclear action.

5. That the young and newly sprouted leaves of trees, such as those of the gooseberry and currant, have no nuclear action.

6. That in clear cloudless weather, when the force of evaporation is strong, the solutions by exposure produce fine groups of crystals of the ten-atom salt, just as a saturated solution would do if left to evaporate slowly in an open dish.

7. That if the solution, after being exposed to the open air, be brought into a room, it crystallizes immediately under the action of aërial nuclei.

On the Constitution of Salts. By J. A. WANKLYN, *F.C.S.*

Recent Progress in Chemistry in the United States. By C. GILBERT WHEELER.

On the Oxidation products of the Essential Oil of Orange-peel, known as "Essence de Portugal." By C. R. A. WRIGHT, *D.Sc., Lecturer on Chemistry in St. Mary's Hospital Medical School, and* CHARLES H. PIESSE, *Assistant Analyst in St. Thomas's Hospital.*

Through the kindness of Messrs. Piesse and Lubin, we have had the opportunity of examining a specimen of *pure* oil of orange-peel. As stated by Soubeiran and Capitaine, and also by Dr. Gladstone, this oil consists mainly of a hydrocarbon of formula $C_{10}H_{16}$, boiling at 174° C., and termed Hesperidene. We find that the crude oil commences to boil at 175°, and that 97·2 per cent. comes over below 179°; on redistillation over sodium this portion all comes over between 175° and 177° (uncorrected). The remaining 2·8 per cent. is a soft resin, which does not harden on standing, and is perfectly fluid at 100°. It is not volatile without decomposition, and after complete volatilization of residual hesperidene is inodorous; in alcohol, even boiling, it is but sparingly soluble, readily soluble in ether, and insoluble in water, to which, however, it communicates the aromatic bitter taste of orange-peel. It contains no nitrogen, and on combustion gives numbers agreeing with the formula $C_{20}H_{30}O_3$.

Hesperidene redistilled over sodium is attacked with violence by concentrated warm nitric acid; by dilution of the acid with its own bulk of water the action becomes less violent; after boiling some hours with an inverted condenser attached, the evolution of red fumes and of CO_2 almost ceases. At this stage the hydrocarbon has principally formed a brown resinous substance, becoming a very thick viscid liquid at 100°, but setting on cooling to a hard brittle mass. This contains much nitrogen and less hydrogen in proportion to the carbon than the original substance. Its examination is not yet completed, but the numbers obtained are consistent with the supposition that it is derived from the original hydrocarbon by addition of oxygen and replacement of hydrogen by NO_2.

With strong nitric acid this brown resin is further acted on, producing a yellow resin not softening at 100°, and containing nitrogen and less carbon and hydrogen than the brown resin. Much oxalic acid is also produced, and probably also another acid containing nitrogen; for the snow-white oxalic acid got by precipitation as lead-salt, decomposition with hydric sulphide, and several recrystallizations from water, contained much nitrogen, and yielded (as well as its silver salt) numbers not agreeing with but approximating to those required by theory.

On heating one part of hesperidene with a mixture of three parts potassium

dichromate, one of sulphuric acid, and thirty of water, an inverted condenser being attached, a slow evolution of CO_2 is noticed. After six or eight hours but little action has apparently taken place; but on distilling the product there is obtained, besides unaltered hesperidene, an acid liquid, which yields by neutralization a barium salt, giving all the qualitative reactions of acetate, and containing the calculated percentage of barium; a little formiate is possibly also produced, as the barium salt reduces silver nitrate slightly on boiling. The silver salt got by precipitation with strong silver nitrate and recrystallization from boiling water is pure acetate.

The action of potassium chlorate and sulphuric acid on hesperidene is very energetic, a viscid tarry substance, not yet examined, being produced.

The production of acetic acid from hesperidene renders a grouping of carbon atoms of the following nature probable:—

$$\begin{array}{l} C\,H_3 \\ CH\,(C_8\,H_{12})''. \end{array}$$

We hope to be able to gain some further insight into the structure of the group $C_8\,H_{12}$, and propose to submit to examination several other essential oils, hoping that the results may throw some light on the causes of the "physical isomerism" of the turpentine group of hydrocarbons.

On certain new Derivatives from Codeia. *By* C. R. A. Wright, *D.Sc., Lecturer on Chemistry in St. Mary's Hospital Medical School.*

When codeia is heated to 100° C. for two or three hours with from three to six parts of aqueous hydrobromic acid containing 48 per cent. HBr, there are formed, without appreciable evolution of methyl bromide, three new bases, of which the two last are produced by a further action on the first. These are—

$$\begin{array}{ll} \textit{Bromocodide} & C_{18}\,H_{20}\,Br\,NO_2 \\ \textit{Deoxycodeia} & C_{18}\,H_{21}\quad NO_2 \\ \textit{Bromotetracodeia} & C_{72}\,H_{83}\,Br\,N_4\,O_{12}. \end{array}$$

The two first are soluble in ether, and may thus be separated (after precipitation by sodium carbonate) from the last, which is almost insoluble in this medium. By agitation of the etherial extract with hydrobromic acid there is obtained a viscid liquid, which contains little but bromocodide hydrobromate, if the digestion of the codeia have been carried on for a short time only, but contains also much deoxycodeia hydrobromate if the digestion have been continued somewhat longer. This latter salt separates in crystals from the viscid liquid on standing, the bromocodide hydrobromate furnishing a gummy mass only on standing and evaporation.

By dissolving the portion insoluble in ether in dilute hydrobromic acid, and fractionally precipitating the coloured solution thus got with strong hydrobromic acid several times successively, bromotetracodeia hydrobromate is ultimately obtained in white amorphous flakes, that become tarry if warmed while moist, and colour more or less on drying. When once dry, a temperature of 100° C. does not soften the amorphous salt.

The following reactions explain the productions of these three bases from codeia hydrobromate—

$$\underset{\text{Codeia hydrobromate.}}{C_{18}\,H_{21}\,NO_3,\,HBr} + HBr = H_2\,O + \underset{\text{Bromocodide hydrobromate.}}{C_{18}\,H_{20}\,Br\,NO_2,\,HBr}$$

$$\underset{\text{Codeia hydrobromate}}{4(C_{18}H_{21}NO_3,HBr)} + \underset{\text{Bromocodide hydrobromate.}}{C_{18}H_{20}BrNO_2,HBr} = \underset{\text{Deoxycodeia hydrobromate.}}{C_{18}H_{21}NO_2,HBr} + \underset{\text{Bromotetracodeia hydrobromate.}}{C_{72}H_{83}BrN_4O_{12},4HBr.}$$

By the further action of hydrobromic acid on each of the above bases methyl bromide is copiously evolved, and the following series of products formed:—

(A) From bromotetracodeia: *bromotetramorphia*, probably by the reaction—

$$\underset{\text{Bromotetracodeia.}}{C_{72}\,H_{83}\,BrN_4\,O_{12}} + 4HBr = 4CH_3\,Br + \underset{\text{Bromotetramorphia.}}{C_{68}\,H_{75}\,BrN_4\,O_{12}.}$$

(B) From bromocodide: probably at first a lower homologue bromomorphide (not yet isolated), converted subsequently into *bromotetramorphia* and *deoxymorphia* by the reaction.

$$\underset{\text{Bromomorphide.}}{5C_{18}H_{78}BrNO_2} + 4H_2O = 4HBr + \underset{\text{Deoxymorphia.}}{C_{17}H_{19}NO_2} + \underset{\text{Bromotetramorphia.}}{C_{68}H_{75}BrN_4O_{12}}.$$

(C) From deoxycodeia: only blackened tarry substances, not fit for analysis; hence probably the deoxymorphia got in B is *not* formed from deoxycodeia previously produced.

Deoxymorphia and bromotetramorphia much resemble in all their properties their homologues deoxycodeia and bromotetracodeia; the first gives crystalline salts, the second amorphous ones.

The constitutions of all the above have been verified by analyses of the hydrobromates, hydrochlorates, platinum salts, &c. In qualitative reactions, the deoxy-salts are identical with apomorphia salts.

On treating bromotetracodeia and bromotetramorphia with excess of cold strong hydrochloric acid, dissolving in water, and fractionally precipitating by strong hydrochloric acid, the bromine in these bases becomes replaced by chlorine, yielding the following bodies, that much resemble in all their properties the corresponding brominated salts:—

Chlorotetracodeia hydrochlorate $C_{72}H_{83}ClN_4O_{12}$, 4HCl
Chlorotetramorphia hydrochlorate $C_{68}H_{75}ClN_4O_{12}$, 4HCl.

By digesting codeia for six hours at 100° with hydrobromic acid, there was obtained a substance that gave numbers (after treatment with hydrochloric acid) intermediate between those required for the two last-named bodies. This may have been only a mixture of these two; but it seems very probable that a series of products should exist intermediate between these extremes, viz.—

$$\begin{aligned}
&C_{68}H_{75}BrN_4O_{12} = \text{Bromotetramorphia}\\
&C_{69}H_{77}BrN_4O_{12}\\
&C_{70}H_{79}BrN_4O_{12}\\
&C_{71}H_{81}BrN_4O_{12}\\
&C_{72}H_{83}BrN_4O_{12} = \text{Bromotetracodeia}\\[4pt]
&C_{68}H_{75}ClN_4O_{12} = \text{Chlorotetramorphia}\\
&C_{69}H_{77}ClN_4O_{12}\\
&C_{70}H_{79}ClN_4O_{12} = \text{Chlorodicodeia-dimorphia}\\
&C_{71}H_{81}ClN_4O_{12}\\
&C_{72}H_{83}ClN_4O_{12} = \text{Chlorotetracodeia.}
\end{aligned}$$

Assuming that this substance was not a mixture, it might be termed chlorodicodeia-dimorphia.

Dr. Michael Foster finds that the tetracodeia and tetramorphia compounds produce in adult cats a great excitement of the nervous system, and apparently paralyze the inhibitory fibres of the pneumogastric. Apparently the morphia compounds are somewhat more potent than the codeia bodies in this case.

Deoxycodeia and deoxymorphia salts produce in adult cats convulsions more epileptic in character than tetanic. No trace of emetic symptoms has been observed with any of the salts of this class of bases, which in physiological effect, as well as chemical reactions, are almost indistinguishable the one from the other.

This absence of emetic symptoms conclusively proves that apomorphia is not among the products of the action of hydrobromic acid on codeia. From its known production from this base by the action of hydrochloric acid, as well as from the analytical numbers obtained, the formation of apomorphia has been previously looked upon as probable.

By the action of hydriodic acid containing 55 per cent. HI on codeia in presence of phosphorus, a series of substances have been formed that present the compositions included in one or other of the two general formulæ,

$$4X + nHI \pm pH_2O,$$
$$4Y + nHI \pm pH_2O,$$

where X represents a base containing two atoms of hydrogen more than morphia ($i.e. = C_{17}H_{21}NO_3$), and Y a base containing one atom of oxygen less than X ($i.e. = C_{17}H_{21}NO_2$). Simultaneously with the production of these substances, iodide of methyl, in quantity representing almost exactly $\frac{1}{18}$ of the carbon in the codeia used, is evolved.

By allowing the action of 10 parts codeia, 30 of 55 per cent. hydriodic acid, and 3 of phosphorus, to take place at 100°, a compound is produced separable from the viscid liquid resulting from the reaction by addition of water, washing, and drying at 100°, and representing in constitution the formula

$$4X + 6HI = C_{68}H_{86}I_2N_4O_{12}, 4HI.$$

If, however, the reaction take place at a somewhat higher temperature, a similar body containing two molecules of water less is formed,

$$4X + 6HI - 2H_2O = C_{68}H_{82}I_2N_4O_{10}, 4HI;$$

whilst if the mixture be allowed to boil rapidly, so as to distil off most of the excess of hydriodic acid employed, and ultimately raise the boiling-point to 130° or upwards, the product contains four atoms of oxygen less than this last compound, being

$$4Y + 6HI - 2H_2O = C_{68}H_{82}I_2N_4O_6, 4HI.$$

Simultaneously with these bodies much phosphorous and phosphoric acids are produced.

On dissolving these substances in hot water and cooling, there are obtained products apparently crystalline to the eye, but under the microscope consisting of coalesced globules only. In this way the following bodies have been obtained:—

$$\begin{aligned} 4X + 5HI - 2H_2O &= C_{68}H_{81}IN_4O_{10}, 4HI \\ 4X + 4HI - 2H_2O &= C_{68}H_{80}N_4O_{10}, 4HI \\ 4Y + 4HI + 2H_2O &= C_{68}H_{88}N_4O_{10}, 4HI. \end{aligned}$$

The free bases of some of the foregoing hydriodates have also been obtained. They oxidize very readily, forming orange-coloured substances that ultimately become black.

Finally, by the action of hydriodic acid on the three bodies of the formulæ last given, the elements of HI and also of H_2O are taken up; the following compounds having been thus obtained,

$$\begin{aligned} 4X + 7HI + 10H_2O &= C_{68}H_{107}I_3N_4O_{22}, 4HI \\ 4Y + 7HI + 8H_2O &= C_{68}H_{103}I_3N_4O_{16}, 4HI \\ 4Y + 5HI + 2H_2O &= C_{68}H_{89}IN_4O_{10}, 4HI. \end{aligned}$$

The H_2O thus taken up remains firmly united to the body of the molecule, exposure to a temperature of 100° for days not driving off any water.

In qualitative reactions, all these bodies are very similar: alkalies throw down a white precipitate of variable composition in the case of those bases which contain iodine united to the molecule of base. In all cases this white precipitate rapidly becomes yellow, orange, and finally brown, oxygen being absorbed. In water and sodium carbonate these precipitates are but little soluble; in ammonia, and especially caustic potash, readily soluble.

Oxidizing agents (*e.g.* nitric acid) produce a bright yellow or orange-yellow tint.

In most of the above reactions, this set of compounds differs much from those got by the action of hydrochloric and hydrobromic acids; the free bases of these latter derivatives having a tendency to become *green* by oxidation in the air, and yielding *red* or *purple* colorations with oxidizing agents.

The codeia used in the experiments above described formed part of a large supply, exceeding twenty ounces, most liberally presented for the purpose by Messrs. J. F. Macfarlane and Co., of Edinburgh.

GEOLOGY.

Address by Archibald Geikie, *F.R.S., President of the Section.*

Instead of offering to the Geological Section of the British Association an opening Address on some special aspect or branch of general Geology, I have thought that it might be more interesting, and perhaps even more useful, if I were to lay before you an outline of the geology of the district in which we are now assembled. Accordingly, in the remarks which I am now about to make, I propose to sketch to you the broader features of the geological structure and history of Edinburgh and its neighbourhood, dwelling more especially on those parts which have more than a mere local interest, as illustrative of the general principles of our science.

It would be as unnecessary as it would be out of place here to cite the long array of authors who have each added to our knowledge of the geology of this district, and many of them also, at the same time, to the broad fundamental truths of geology. And yet it would be strange to speak here of the rocks of Edinburgh without even a passing tribute of gratitude to men like Hutton, Hall, Jamieson, Hay Cunningham, Hibbert, Hugh Miller, Fleming, Milne Home, and our late esteemed and venerable associate, Charles Maclaren—men who have made the rocks of Edinburgh familiar to geologists all over the world. If, therefore, I make no further allusion to these and other names, it is neither that I forget for a moment their claims, nor that I now bring forward any new material of my own, but because I wish to be understood as dealing with facts which, thanks to the labours of our predecessors, have become part of the common stock of geological knowledge.

For the purpose of gaining as clear an idea as may be of the rocks among which Edinburgh lies, and of the way in which they are grouped together, let us imagine ourselves placed on the battlements of the Castle, where, by varying our position, we may obtain a clear view of the country in every direction for many miles round. To the south-east the horizon is bounded by a range of high ground, rising as a long tableland above the lowland of Midlothian. That is a portion of the wide Silurian uplands of the south of Scotland, forming here the chain of heights known as the Lammermuir and Moorfoot Hills. Along most of its boundary line, in this district, the Silurian tableland descends with tolerable rapidity towards the plain, being bounded on its north-west side with a long fault, by which the Carboniferous rocks are brought down against the hills. These Silurian rocks are the oldest strata of the district; and it is on their contorted and greatly denuded beds that the later formations have been laid down.

Turning now to the south, we see the chain of heights known as the Pentland Hills, striking almost from the very suburbs of Edinburgh south-westward in the direction of the Silurian uplands, which they eventually reach in the county of Lanark. This line of hills rises along an anticlinal axis by which the broad Carboniferous tract of the Lothians is divided into two distinct portions. The Pentlands themselves consist, as I shall afterwards point out, chiefly of rocks of Old Red Sandstone age; but the anticlinal fold along which they rise is prolonged through the Braid Hills, and through the Carboniferous ground by the Castle Rock of Edinburgh, even as far as the opposite shores of Fife. From the Castle we can readily follow with the eye the effects of this great dominant fold of the rocks. To the east, we mark how the strata dip away eastward from the axis of movement, as is shown in the escarpments of Salisbury Crag, Arthur's Seat, and Calton Hill, while on the opposite or western side the escarpment of the wooded hill of Corstorphine, facing towards us, points out the westward dip. From the same standpoint we can even detect the passage of the arch into Fife; for the rocks about Aberdour are seen dipping to the west, while eastward they bend over and dip towards the east at Kinghorn.

Although the structure of the district is simple when the existence and position of this anticlinal axis is recognized, some little complication is introduced by a long powerful fault which flanks the axis on its south-eastern side. The effect of this fault is to throw out a great part of the lower division of the Carboniferous formations, and to bring the Carboniferous Limestone series in some places close

against the Lower Old Red Sandstone and its volcanic rocks. Another result has been the extreme tilting of the strata, whereby the Limestone series along the east side of the fault has been thrown on end, and even in some parts bent back into a reversed dip. Hence, while on one side of the axis the Limestone series is sometimes only a few hundred yards distant from the Old Red Sandstone, on the opposite or north-west side the distance is fully eleven miles, the intervening space being there occupied by endless undulations of the lower divisions of the Carboniferous system. Hence, too, the Millstone-grit and Coal-measures come in along the centre of the Midlothian basin a short way to the east of the Pentland axis; while on the west side they are not met with till we reach the borders of Stirlingshire and Linlithgow.

Another remarkable and readily observable feature is, that on the west side of the Pentland ridge the Carboniferous formations, from almost their base up to the top of the Carboniferous Limestone series, abound in contemporaneous volcanic rocks; while on the east side, beyond Edinburgh and Arthur's Seat, such rocks are absent until we reach the Garlton Hills, to the north of Haddington, where they reappear, but in a very different type from that which they exhibit to the west.

Let us now pass in review the different geological formations which come into the district around us, beginning with the oldest and ascending through the others till we reach the superficial accumulations, and mark, in conclusion, how far the present surface-features are connected with geological structure.

[The author then described the various geological formations of the district—Silurian, Old Red Sandstone, and Carboniferous—dwelling in particular upon the history of volcanic action in that part of Scotland. On this subject he remarked:—]

Outline of the History of Volcanic Action around Edinburgh.

The oldest volcanoes of this part of Scotland were those which, during the time of the Lower Old Red Sandstone, poured out the great sheets of porphyrite and the showers of tuff which now form the main mass of the range of the Pentland Hills. During the same long geological period volcanic action was rife, as we have seen, along the whole of the broad midland valley of Scotland, since to that time we must refer the origin of the Sidlaw and the Ochil Hills, part of eastern Berwickshire, and the long line of uplands stretching from the Pentland Hills through Lanarkshire, and across Nithsdale, far into Ayrshire.

Of volcanic action, during the remainder of the Old Red Sandstone period, there is around Edinburgh no trace. But early in the following or Carboniferous period, the volcano of Arthur's Seat and Calton Hill came into existence, and threw out its tiny flows of basalt and porphyrite, and its showers of ashes. From that time onwards, through nearly the whole of the interval occupied by the deposition of the Carboniferous Limestone series, the district to the west of Edinburgh was dotted over with small cones, usually of tuff, but sometimes emitting limited currents of different basalt rocks, more especially in the space between Bathgate and the Forth, where a long bank, chiefly formed of such lava-currents, was piled up over and among the pools and shallows in which the limestones, sandstones, shales, and coal-seams were accumulated. To the north, also, similar volcanic activity was shown in the Fife tracts nearest the Forth; while eastwards, between Haddington and Dunbar, there lay a distinct volcanic focus, where great showers of red felspathic tuff and widespread sheets of porphyrite were ejected to form a bank over which the Carboniferous Limestone series was at length tranquilly deposited.

Volcanic activity seems to have died out here before the close of the Carboniferous Limestone period. It remained quiescent during the deposition of the Millstone-grit and Coal-measures; at least no trace of any contemporaneous igneous ejection is found in any part of these formations. The intrusive masses of various basalt rocks, which here intersect the older half of the Carboniferous system, are, in all probability, of Lower Carboniferous date, connected with the eruptions of the interbedded volcanic rocks. The next proofs of volcanic action in this neighbourhood are furnished by the upper part of Arthur's Seat. At that locality we discover that after more than 3000 feet of strata had been removed by denudation from the Pentland anticlinal fold so as to lay bare the old Lower Carboniferous volcanic rocks of Edinburgh, a new focus of eruption was formed, from which

were ejected the basalts and coarse agglomerates of the summit and shoulders of Arthur's Seat. There is no trustworthy evidence for fixing the geological date of this eruption. Evidently, from the great denudation by which it was preceded, it must belong to a much later period than any of the Carboniferous eruptions. Yet, from the great similarity of the Arthur's Seat agglomerate, both in composition and mode of occurrence, to numerous "necks" which rise through all parts of the Carboniferous system between Nithsdale and Fife, and which I have shown to mark the position of volcanic orifices during Permian times, I am inclined to regard these later igneous rocks of Edinburgh as dating from the Permian period. Arthur's Seat, however, seems to have been the only volcano in action during that period in this neighbourhood.

There still remains for notice one further and final feature of the volcanic history of this part of Scotland. Rising indifferently through any part of the other rocks, whether aqueous or igneous, and marked by a singular uniformity of direction, there is a series of basalt dykes which deserves attention. They have a general easterly and westerly trend, and even where, as in Linlithgowshire, they traverse tracts of basalt-rocks, they preserve their independence, and continue as readily separable as when they are found intersecting sandstones and shales. These dykes belong to that extensive series which, running across a great part of Scotland, the north of England, and the north-east of Ireland, passes into, and is intimately connected with, the wide basaltic plateaux of Antrim and the Inner Hebrides. They date, in fact, from Miocene times, and, from their numbers, their extent, and the distance to which they can be traced from the volcanic centre of the north-west, they remain as a striking memorial of the vigour of volcanic action during the last period of its manifestation in this country.

Glacial Phenomena.

To an eye accustomed to note the characteristic impress of ice-action upon a land-surface, the neighbourhood of Edinburgh presents many features of interest. It was upon Corstorphine Hill, on the western outskirts of the city, that Sir James Hall first called attention to striated rock-surfaces which, though erroneously attributed to the abrasion produced by torrents of water, were even then recognized as trustworthy evidence of the last great geological changes that had passed over the surface of the country. Even before we come to look at the surface in detail, and note the striation of its rocks, we cannot fail to recognize the distinctively ice-worn aspect of the hills round Edinburgh. Each of them is, in fact, a great *roche moutonnée*, left in the path of the vast ice-sheet which passed across the land. That this ice was of sufficient depth and mass to override even the highest hills, is proved not merely by the general ice-worn surface of the landscape, but by the occurrence of characteristic striæ on the summits of the Pentland Hills, 1600 feet above the sea; that it came from the Highlands, is indicated by the pebbles of granite, gneiss, schist, and quartz rock occurring in the older boulder-clays which it produced; and that, deflected by the mass of the southern uplands, the ice in the valley of the Lothians was forced to move seawards, in a direction a little north of east, is shown by the trend of the striæ graven on the rocks, as at Corstorphine, Granton, Arthur's Seat, and Pentland Hills.

Connexion of the present form of the Surface with Geological Structure.

In concluding these outlines, let me direct the attention of the Section to the bearing which the geological structure of the district wherein we are now assembled has upon the broad and much canvassed question of the origin of land-surfaces. In the first place, we cannot fail to be struck with the evidence of enormous denudation which the rocks of the district have undergone. Every formation, from the oldest to the latest, has suffered, and the process of waste has been going on apparently from the earliest times. We see that the Lower Silurian rocks were upheaved and denuded before the time of the Lower Old Red Sandstone; that the latter formation had undergone enormous erosion before the beginning of the Carboniferous period; that of the Carboniferous rocks, a thickness more than 3000 feet had been worn away from the site of Arthur's Seat before the last eruptions of that hill, which are possibly as old as the Permian period

that still further and vaster denudation took place before the setting in of the Ice-age; and finally, that the deposits of that age have since been to a large extent removed. With the proofs, therefore, of such continued destruction, it would be vain to look for any aboriginal outline of the surface, or hope to find any of the later but still early features of the landscape remaining permanent amid the surrounding waste.

In the second place we note that, in the midst of this greatly denuded area, it is the harder rocks which form the hills and crags. Those masses which in the long process of waste presented most resistance to the powers of destruction, are just those which, as we might expect, rise into eminences, while those whose resistance was least sink into plains and valleys. All the craggy heights which form so conspicuous a feature of Edinburgh and its neighbourhood, are composed of hard igneous rocks, the undulating lowlands lie upon soft aqueous rocks.

In the third place, the coincidence of the position of hills and crags with the existence of ancient igneous rocks, cannot be misinterpreted by ascribing the presence and form of the hills to the outlines assumed by the igneous material ejected to the surface from below. The hills are not due to igneous upheaval at all, but can be shown to have been buried deep under subsequent accumulations, to have been bent and broken with all the bendings and breaks these later formations underwent, and to have been finally brought to light again only after a long cycle of denudation had removed the mass of rock under which they had been concealed. What is true of the hills of Edinburgh, is true also of all the older volcanic districts o Britain. Even where the hills consist of volcanic rocks, their existence, as hills, can be proved to be one of the results not of upheaval but of denudation.

In the fourth place, this district furnishes an instructive illustration of the influence of faults upon the external contour of a country. The faults here do not form valleys. On the contrary, the valleys have been cut across them in innumerable instances. In the Dalkeith coal-field, for example, the valleys and ravines of the river Esk traverse faults of 190 to nearly 500 feet, yet there is no inequality at the surface, the whole ground having been planed down by denudation to one common level. When, however, a fault brings together rocks which differ much in their relative powers of resistance to waste, the side of the dislocation occupied by the harder rocks will tend to form an eminence, while the opposite side, consisting of softer rocks, will be worn down into a hollow or plain. Conspicuous examples are furnished by the faults which, along the flanks of the Pentland Hills, have brought down the comparatively destructible sandstones and shales of the Carboniferous series, against the much less easily destroyed porphyrites and conglomerates of the Old Red Sandstone.

In fine, we learn here as elsewhere in our country, and here more strikingly than often elsewhere, on account of the varied geological structure of the district, that the present landscape has resulted from a long course of sculpturing, and that how much soever that process may have been accelerated or retarded by underground movements, it is by the slow but irresistible action of rain and frost, springs, ice, and the sea, that out of the various geological formations among which Edinburgh lies, her picturesque outline of hill and valley, crag and ravine, has, step by step, been carved.

The Yorkshire Lias and the Distribution of its Ammonites. *By the* Rev. J. F. Blake.

The Lias of Yorkshire is exposed on the coast for a distance of about 30 miles, and owing to faults and undulations the series is repeated twice, one main area being to the north, the other to the south of Whitby; and there are two outlying patches, one of the highest beds at Peak, the other of the lowest beds at Redcar.

The basis of the description in this paper is the division into Ammonite zones, as by Oppel and others.

1. Zone of *Ammonites Jurensis.*—These occur at Peak. The author has not found the characteristic Ammonite *in situ,* but recognizes the zone by its peculiar fauna. It appears to be divided into an upper and lower division.

2. Zone of *Posidonia Bronnii.*—This the author divides into several.

a. Zone of *Am. bifrons.*—Containing bands of cement stone.

β. Zone of *Am. communis.*—Constituting the alum-shale, and characterized throughout by *Leda ovum.*

γ. Zone of *Posidonia Bronnii* proper, which includes the jet-bearing beds. These form the Upper Lias.

3. Zone of *Am. spinatus.*—This consists of numerous ironstone bands, which form the workable beds of Yorkshire.

4. Zone of *Am. margaritatus.*—More micaceous beds.

These two zones are not clearly separable, both Ammonites being found in each.

5. Zone of *Am. Davæi.*—This Ammonite is very rare, if found at all, in Yorkshire, and the zone is more characterized by *Am. capricornus.*

6. Zone of *Am. Ibex.*—This form is now recognized for the first time in Yorkshire, but the associated Ammonites, *Henleyi* and *fimbriatus,* form a well-marked zone.

7. Zone of *Am. Jamesoni.*—The true form only found *in situ* north of Whitby; but the allied *brevispina* is highly characteristic of the beds, which are very fossiliferous.

8. Zone of *Am. armatus.*—This is well represented; the *Pinna folium* is conterminous with the two last zones, which end the Middle Lias.

The last four zones are similar in lithological character, being shaly beds with scattered dogger bands.

The zones below this are only seen at Robin Hood's Bay and Redcar.

9. Zone of *Am. raricostatus.*—This is well developed in micaceous shaly beds, indurated at the top, which is the character also of all the succeeding zones.

10. Zone of *Am. oxynotus.*—Also well developed, containing a strong limestone band.

11. Zone of *Am. Turneri.*—Is only found on the shore.

12. Zone of *Am. obtusus.*—Seen at Peak.

13. Zone of *Am. Bucklandi.*—Forms the lowest beds seen at Robin Hood's Bay, and the highest at Redcar. They do not contain limestone as elsewhere. An ichthyosaur has been found in these, such having been hitherto only announced from the Upper Lias in Yorkshire.

14. Zone of *Am. angulatus.*—This is represented by thin shaly beds at Redcar, where this Ammonite is abundant; and also by a limestone-bed near Market Weighton, at which latter place it contains a new and varied fauna.

15. Zone of *Am. planorbis.*—Hitherto only washed up from the sea in fragments. Its beds have now been discovered near Market Weighton, where they contain numerous foraminifera. In this locality the oyster-bands and white lias are reached, but not the bone-bed.

The lithological character and the position of all these zones were described in the paper.

List of Ammonites in the Author's Cabinet from the several Zones.

Those marked P have not been found *in situ*, but their belonging to the zone is almost certain; those marked *p* probably belong to the zone.

Zone of *Ammonites Jurensis.*

Ammonites Aalensis (*Ziet.*).
—— striatulus (*Sow.*).
—— compactilis (*Simp.*).
—— lectus (*Simp.*).
P —— Jurensis (*Ziet.*). = gubernator (*Bean*).
P —— variabilis (*D'Orb.*) = Beanii (*Simp.*) = obliquatus (*Simp.*).
p —— fabalis (*Simp.*) = Escheri (*Hauer*)?

Zone of *Ammonites bifrons.*

Ammonites bifrons (*Brug.*) = Walcottii (*Sow.*).
—— Levisoni (*Simp.*) = Sæmanni (*Opp.*).
—— heterophyllus (*Y. & B.*).
Ammonites crassus (*Y. & B.*) = Raquinianus (*D'Orb.*).
—— Lythensis (*Y. & B.*).
—— Mulgravius (*Y. & B.*).

Zone of *Ammonites communis.*

Ammonites communis (*Sow.*).
—— delicatus (*Simp.*).
—— Braunianus (*D'Orb.*).
—— Mulgravius (*Y. & B.*).

From one or other of the above zones.

Ammonites Eseri (*Oppel*).
—— Desplacei (*D'Orb.*).
—— fibulatus (*Y. & B.*).

Ammonites Andreæ (*Simp.*).
—— crassifactus (*Simp.*). varieties of crassus.
—— crassescens (*Simp.*). varieties of crassus.
—— vortex (*Simp.*). varieties of crassus.
—— fonticulus (*Simp.* varieties of crassus.

Zone of *Posidonia Bronnii.*

Ammonites Mulgravius (*Y. & B.*).
—— serpentinus (*Schl.*).
—— ovatus (*Y. & B.*).
—— elegans (*Sow.*).
—— exaratus (*Y. & B.*).
—— Aalensis (*Ziet.*) = rugatulus (*Simp.*).
—— concavus (*Sow.*).
—— delicatus (*Simp.*).
—— annulatus (*Sow.*).
—— heterophyllus (*Y. & B.*).
P —— semicelatus (*Simp.*).
P —— attenuatus (*Simp.*).
P —— Easingtonensis (*Simp.*).
p —— subcarinatus (*Y. & B.*).
p —— subconcavus (*Y. & B.*).
p —— latescens (*Simp.*).

Zone of *Ammonites spinatus.*

Ammonites spinatus (*Brug.*). Common.
—— margaritatus (*Schl.*). Rare.
—— conjunctivus (*Simp.*) = spinellii, (*Hau.*).
—— reticularis (*Simp.*) (= Engelhardtii, *D'Orb.*)??
P —— lenticularis (*Y. & B.*) = coynarti (*D'Orb.*).

Zone of *Ammonites margaritatus.*

Ammonites margaritatus (*Schl.*). Common.
—— spinatus (*Brug.*). Very scarce.
—— nitescens (*Y. & B.*) = stahli (*Opp.*).
—— n. sp., No. 1.
p —— n. sp., No. 2.

Zone of *Ammonites capricornus.*

Ammonites capricornus (*Schl.*) = maculatus (*Y. & B.*).
—— arcigerens (*Ph.*).
P —— curvicornis (*Schlönb.*).
P —— subarmatus (*Y. & B.*).

Zone of *Ammonites Henleyi.*

Ammonites Henleyi (*Sow.*).
—— fimbriatus (*Sow.*).
P —— Davidsoni (*D'Orb.*) = lævigatus (*Sow.*) = nitidus (*Y. & B.*)?
P —— ibex (*Qu.*).

Zone of *Ammonites Jamesoni.*

Ammonites Jamesoni (*Sow.*).
—— brevispina (*Sow.*).
—— caprarius (*Qu.* = aureus (*Simp.*).
—— venustulus (*Dum.*).
—— natrix (*Schl.*).
—— lynx (*D'Orb.*) = lens (*Simp.*).

Ammonites polymorphus (*Qu.*) = trivialis (*Simp.*).
—— Dennyi (*Simp.*) = heterophyllus numismalis (*Qu.*)
—— aculeatus (*Simp.*).

Zone of *Ammonites armatus.*

Ammonites armatus (*Sow.*).
—— cornutus (*Simp.*) = Taylori costatus (*Qu.*).
—— Taylori (*Sow.*).
—— submuticus (*Dum. non Opp.*).
—— Macdonnellii (*Portl.*).
—— tubellus (*Simp.*) = miserabilis (*Qu.*).
—— tardicrescens (*Hauer*).
—— n. sp., No. 3.

Zone of *Ammonites raricostatus.*

Ammonites raricostatus (*Ziet.*).
—— densinodus (*Qu.*).
—— subplanicosta (*Opp.*).

Zone of *Ammonites oxynotus.*

Ammonites oxynotus (*Qu.*).
—— Simpsoni (*Simp.*).
—— gagateus (*Y. & B.*).

Zone of *Ammonites obtusus.*

Ammonites obtusus (*Sow.*).
—— stellaris (*Sow.*).
—— planicosta (*Sow.*).
—— Ziphus (*Ziet.*).
—— n. sp. No. 4.
—— n. sp. No. 5.
p —— Scipionanus (*D'Orb.*).

Zone of *Ammonites Turneri.*

Ammonites Turneri (*Sow.*).
—— geometricus (*Opp.*).
—— Youngi (*Simp.*).
P —— impendens (*Y. & B.*) = Fowleri (*Buckm.*).
P —— tenellus (*Simp.*). = denotatus (*Simp.*).

Zone of *Ammonites Bucklandi.*

Ammonites Bucklandi (*Sow.*).
P —— Conybeari (*Sow.*).
—— bisulcatus (*Brug.*).
—— spinaries (*Qu.*).
—— semicostatus (*Y. & B*) = Hartmanni (*Opp.*).
—— Sauzeanus (*D'Orb.*). = transformatus (*Simp.*).
—— Birchii (*Sow.*).
—— difformis (*Emm.*).
—— compressaries (*Qu.*).
—— multicostatus (*Sow.*).

Infralias.

Ammonites angulatus (*Schl.*).
—— Johnstoni (*Sow.*) = psilonotus plicatus (*Qu.*).
—— planorbis (*Sow.*).

On the Silurian Rocks of the South of Scotland. *By* D. J. Brown.

This paper was illustrated by a map and section, also specimens of rocks and fossils.

In a section drawn from Moffat Water in Dumfriesshire to Kilbucho in Peeblesshire, we have, first, the Moffat rocks, which consist of hard blue *grit* (*Greywacké*) and shale. These are accompanied by beds of anthracite and black shale containing *Graptolites*; on leaving Moffat Water, we first meet anthracite beds, then a series of grit and shale; this order is repeated six times. The last time we see anthracite beds is at Holmes-water-head, where we find them plunging under the limestone and conglomerate of Wrae and Glencotho, over the whole length of the section from Moffat Water to Holmes Water. The beds stand at a high angle, and have an almost uniform northernly dip. From Holmes Water to Kilbucho the rocks are of a more diversified character. We have first a coarse angular conglomerate, then a bed of limestone with fossils, mostly of a Caradoc type; next a series of beds of slate, shale, and grit; these beds come up again at Kilbucho. After Holmes Water we have no longer the uniform northernly dip, but the beds undulate, and in one section are seen to form regular waves.

These beds all along the line of the section, from the river Tweed to Kilbucho, are given in the Government Geological Map of Peeblesshire as one series of Llandeilo age. The author is of opinion that they form two series—a lower Moffat or Llandeilo, and an upper or Caradoc series that lies unconformable upon the lower.

The author has come to the conclusion that the two series are unconformable:—First, because we find the anthracite beds at a high angle plunging under the limestone and Conglomerate of Glencotho and Wrae at Holmes-water-head, and emerging at the same angle in the Moor-foot Hills. Second, because we find these upper rocks everywhere underlaid by a bed of coarse angular Conglomerate; and this conglomerate is found in fragments, and nowhere *in situ*, in the neighbourhood of Moffat, which is on the opposite watershed, being, as the author thinks, fragments of the lower rocks left in the process of denudation. Third, this Conglomerate is found to contain numerous fragments of anthracitic shale containing *Graptolites* belonging to lower beds, proving that the lower rocks were consolidated, and then torn into fragments before the upper rocks were laid down.

On the Upper Silurian Rocks of the Pentland Hills and Lesmahago. *By* D. J. Brown.

This paper was illustrated by a map and two sections.

In a paper published in the Transactions of the Edinburgh Geological Society, vol. i., written by Mr. Henderson and the author, it was shown that in the North Esk section of the Pentland Hills there is a very perfect Wenlock fauna, and that it is only towards the top of the section that the Ludlow species come in; it was further shown, from Silurian fossils collected from the Red Conglomerate lying at the top of the section, that these Red Conglomerates were not a part of the Lower Old Red Sandstone, but a continuation of the Silurian, and that the whole Silurian rocks in the Lyne water form a continuous section above them. In the district of Lesmahago the Upper Silurians are said to form a continuous series with the Lower Old Red Sandstone that lies above them. In "Memoir 32, Geological Survey of Scotland," the same phenomena are said to occur in the Pentlands, and Mr. Salter draws a parallel between these beds and those of Lesmahago; but from this comparison he omits the section in the Lyne water, which forms a continuous series above the Red Rocks, said to be Old Red Sandstone, so that these Old Red Sandstone beds of the Government Survey lie right in the centre of the continuous section of Upper Silurian, and contain Upper Silurian fossils. As it is only towards the top of the North Esk section that we find any fossils belonging to the Lesmahago beds, and they differ from them very much in their lithological character, the author is of opinion that these beds are not the equivalent of the Lesmahago beds but that these latter form an upper series overlying the Pentland beds.

Geological Notes on the Noursoak Peninsula and Disco Island in North Greenland. *By* Robert Brown, *M.A., Ph.D., F.R.G.S., &c.*

The geology of Greenland has been partially investigated, so far as the west coast is concerned, by Giesecke, Pingel, Rink, and to some extent by Inglefield, Sutherland, Kane, Hayes, and the late Mr. Olrik, so many years Inspector of North Greenland and Director of the Kgl. Grönlandske Handel in Copenhagen. More recently the author and his companions made sections and collected fossils from the vicinity of the localities named; and this paper was an account of the geological results of this voyage, made in 1867. Since then several Swedish naturalists have visited the country, and the German Expedition to East Greenland has added to our knowledge of the geology and tertiary flora of East Greenland. The formations found in Greenland are:—

(1) *Primitive rocks*, chiefly syenite, granitic, and various gneissose rocks, very widely distributed, reaching in some places to a height of 4000 feet or more. In this formation are found the chief economic minerals of Greenland, kryolite, soapstone, &c.

(2) "*The Red Sandstone of Igalliko Fjord*," probably Devonian, but only a patch, now being rapidly destroyed by the sea.

(3) *Mesozoic rocks*: only a patch in the vicinity of Omenak, most probably cretaceous.

(4) *Miocene*: confined entirely to the vicinity of the Waigatz Strait and part of Omenak Fjord, on the west coast, though most probably it once extended right over Greenland in that line, though now either destroyed or overlain by the great interior ice. It makes its appearance on the east coast, and is also found in Spitzbergen.

The next portion of Dr. Brown's paper was occupied in describing in detail the Miocene beds and sections seen at various places; the whole concluding with a criticism of the conclusions of Professor Heer, of Zurich, who had described the plants discovered by Dr. Brown and others, and in giving what he considered was a just view of the results which the palæontologist might logically deduce from the facts already observed. After giving some account of Greenland coal, its structure, chemical composition, and economic value, he furnished a list of the animal- and plant-remains already found in the Miocene and Cretaceous beds in Greenland, and indicated what points remain still to be investigated. Chief among these he instanced the Mesozoic deposits already mentioned. As the Association had already voted a sum of money for this purpose, he thought that if it was judiciously expended through means of some of the well-educated and intelligent Danish officers resident in Greenland, who were accustomed to such work, good results might be accomplished.

Note on certain Fossils from the Durine Limestone, N.W. Sutherland. *By* Dr. Bryce, *F.R.S.E.*

On the Vegetable Contents of Masses of Limestone occurring in Trappean Rocks in Fifeshire, and the conditions under which they are preserved. *By* W. Carruthers, *F.R.S.*

The shore to the east of Kingswood End is strewn with large fragments of a limestone which Mr. G. Grieve, of Burntisland, detected to be filled with vegetable remains. This limestone was traced by Mr. Grieve to the cliffs above, where he found it enclosed in the centre of the trappean tuff. Having received from him several specimens, the author recently spent some time, in company with Prof. Morris, in investigating this important discovery of Mr. Grieve, under his direction. The specimens occur in angular masses in the volcanic ash, and are fragments of beds existing before the formation of the bed of ash. At Elie fragments of coniferous wood abound in a similar bed, and there, as at Kingswood End, the ash contains numerous fragments of shale, limestone, sandstone, &c. The author believed that the plant-remains had been enclosed in the form of peat, from a

surface bed, where the coal-plants were growing when the ash was thrown out of the volcano, the lime abounding in the bed, and which fills the numerous amygdaloidal cavities of the rock, having speedily seized and fixed them, preserving all the details of the tissue. The plants are stems, fruits and leaves of carboniferous plants, and innumerable roots penetrate the mass in every direction. The characters of these plants are beautifully shown on the shore fragments, which are polished by blown sand. At this place the great power of air-driven sand is very evident on the black basalt, which is all smoothed and almost glazed on its western aspect. The author believed that the continuous bed of limestone containing vegetables, above Kingswood End, was different from the blocks on the shore and those in the trappean ash, because of the different mineral conditions and organic contents.

On the General Conditions of the Glacial Epoch; with Suggestions on the formation of Lake-basins. By JOHN CURRY.

The paper contains a detailed topographical account of glacial drift in the north of England, from which the author passes on to discuss the general conditions of the glacial epoch. Increase and diminution of a polar ice-cap is the cause, in the author's judgment, of the movements of subsidence and elevation of sea-level of the glacial period. He maintains that the submerged forests of many parts of the coast have been preserved by being imbedded in a sheet of ice. Remarks on the origin of lake-basins follow. The author cites evidence to show the power of ice and débris to dam up streams, and bases his conclusions largely upon facts quoted from Mr. Jamieson's paper in vol. i. of the Geological Journal.

On the General Geology of Queensland. By R. DAINTREE.

This paper was illustrated by a series of photographs; a number of fossils and rock specimens had been collected by the author, but they were, unfortunately, all lost in the wreck of the 'Queen of the Thames.' The author recognized in Queensland metamorphic and igneous rocks, and the equivalents, to some extent, of our Silurian, Devonian, Carboniferous, Liassic (?), Oolitic, and Cretaceous formations. A still higher series of sandstones occurred, but their precise age had not yet been determined. Alluvial deposits fringed all the water-courses, and had yielded remains of extinct marsupials. It was in these alluvial deposits that the miner met with his chief supply of "free" gold. In the beds which Mr. Daintree refers with doubt to the Lias, coal-seams of varied quality occur. They are only employed for local purposes, and no attempt has yet been made to ascertain their number and relative position. This coal-field occupies a certain district in the south of Queensland, but another coal-field, belonging to the Carboniferous formation, is met with in the north. None of the coals there have been worked, owing to the want of railway communication. In the passage-beds between the Carboniferous and Devonian formations, auriferous lodes occur, all the mineral veins of the country appearing either in Upper Palæozoic or Metamorphic rocks. Copper and lead-ore also abound. The author believes there is a close connexion between the occurrence of veins and the appearance of Trappean disturbance.

The Relation of the Quaternary Mammalia to the Glacial Period. By W. BOYD DAWKINS, *F.R.S.*

The animals fell naturally into five distinct groups, the first of which comprises those now living in the temperate regions of Europe and America, including the Grizzly Bear, the Lynx, the Bison, and the Wild Boar, and binds the Quaternary to the present fauna. The second group comprises those animals which are now confined to cold regions, such as the Glutton, Reindeer, Musk Sheep, and the Tailless Hare; they constitute the Arctic division of Quaternary Mammalia, and imply a cold climate. The third group consists of those animals which are now only found in hot regions, the Hyæna and Hippopotamus; and they indicated

a hot climate. The only mode of getting over this discrepancy is to suppose that in those days the winter cold was very severe, and the summer heat intense, so that in the summer time the animals, now found in warmer regions, migrated northwards, and in the winter time those now found in the Arctic regions went southwards. The fourth group consists of such extinct forms as the Cave Bear, the Stag, the Mammoth, and the Woolly Rhinoceros. The fifth group includes the Sabre-toothed Tiger, the Irish Elk, *Rhinoceros megarhinus* and *R. hemitœchus*, and they, with some others, show that there is no great break between the Quaternary and the Pliocene, such as would warrant any sharply defined division of great value. The interest centered more particularly in the Arctic group; and so far as the evidence went, it seemed to be extremely probable that they were in occupation of the areas in Great Britain in which they were found during the time the other areas, in which they were not found, were covered with glaciers; and this period may be put down to that of the latest sojourn of the glaciers in the highest grounds of our islands, and even so far south as the districts of Auvergne and Dauphiné.

On the Progress of the Geological Survey in Scotland. By Prof. GEIKIE, *F.R.S.*

When the British Association last met in Scotland, I had the honour of bringing before this Section a report upon the progress of the Geological Survey, from the time of its commencement here in 1854 by Professor Ramsay, under the direction of the late Sir Henry De la Beche, up to the year 1867, under the supervision of the present Director, Sir Roderick Murchison. During the four years which have since elapsed, considerable advance has been made in the survey of the southern half of Scotland; and I propose now, with the sanction of Sir Roderick, to present to you a brief outline of what has been done, and of the present state of the Survey.

At the time of my previous report rather more than 3000 square miles had been surveyed. Since then we have completed 2700 square miles additional, making a total area of nearly 6000 square miles. Of this area 3175 square miles have been published on the one-inch scale, and three sheets, representing in all 632 square miles, are now in course of being engraved. The whole country is surveyed upon the Ordnance Maps on the scale of six inches to a mile, and from these field-maps the work is reduced to the one-inch scale, which is the scale adopted for the general Geological Map of the country. In addition to that general map, however, maps on the larger or six-inch are published of all mineral tracts. In this way five sheets of the six-inch maps have now been published, embracing the whole of the coal-fields of Fife, Haddingtonshire, and Edinburghshire, with a large portion of the coal-fields of Lanarkshire, Renfrewshire, Ayrshire, and Dumfriesshire.

The area over which the field-work of the Survey has extended lies between the mouths of the Firths of Tay, Forth, Clyde, and Solway, eastwards to the borders of Roxburghshire and the mouth of the Tweed. It includes the counties of Fife, Kinross, the Lothians, Lanark, Renfrew, Peebles, Ayr, Wigton, Kirkcudbright, Dumfries, and Selkirk, with parts of Stirling, Dumbarton, and Perth.

Of the geological formations examined, the Lower Silurian rocks of the southern uplands cover a considerable space upon the published maps. Until three years ago the mapping of these rocks continued to be most unsatisfactory, owing to the want of any continuous recognizable section from which the order of succession among the strata could be ascertained, and to the great scarcity of organic remains. Our more recent work among the Leadhills, however, has at last given us the means of unravelling, as we hope, the physical structure and stratigraphical relations of the uplands of the south of Scotland. The rocks there are capable of division into several well-marked groups of strata, characterized by distinct assemblages of fossils. We have a lower or Llandeilo series, with a suite of graptolites, and forming probably an upper part of the Moffat group, and a higher or Caradoc set of beds, with a considerable assemblage of distinctive fossils. This higher group we believe to be on the same general horizon as the limestones of Wrae and Kilbucho in Peeblesshire.

The Lower Old Red Sandstone has now been mapped completely over the whole of its extent between Edinburgh and the south of Ayrshire. Fossils have only

been met with at one locality in the latter county, where *Cephalaspis* occurs. The most characteristic feature of the formation is the enormous development of its interbedded volcanic rocks. Between Edinburgh and Lanarkshire, also, there occurs in this formation a local but violent unconformability, connected probably with some phase of the contemporaneous volcanic activity of the region.

Most of the detailed work of the Survey has lain upon Carboniferous rocks. In the lowest formations of this system, known as the Calciferous Sandstones, the Survey has now been able to trace a twofold division completely across the country, from sea to sea, viz. a lower group of red sandstones, and a higher group of white sandstones, green, grey, and dark shales, cement-stones, limestones, and occasional coal-seams. All these strata lie beneath the true Carboniferous Limestone. They are becoming daily more important from their containing in some places highly bituminous shales, from which paraffin oil can be made. The Carboniferous Limestone series, with its valuable coals and ironstones, has been mapped, and in great part published, for the eastern and south-western coal-fields; and this is also the case with the Coal-measures. Much additional information has been obtained regarding the development of volcanic action in central Scotland during the Carboniferous period.

The Permian basins of Ayrshire and Thornhill have been surveyed and in great part published. Much fresh light has in the course of this Survey been thrown on the interesting Permian volcanoes of the south-west of Scotland.

Attention has been continuously given to the superficial accumulations. These are now mapped in as great detail as the rocks underneath, and plans are being prepared with the view to an issue of maps of the surface geology.

By a recent order of the Director-General, each one-inch map is now accompanied at the time of its publication, or as soon thereafter as possible, with an explanatory pamphlet, in which the form of the ground, geological formations, fossils, rocks, faults, and economic minerals are briefly described, and such further information given as seems necessary for the proper elucidation of the map. These pamphlets are sold at a uniform price of 3*d*. Detailed vertical sections are published for each coal-field. For the construction of these sections, records of boring operations are procured and recorded in the register-books of the Survey. Since 1867 more than 312,200 feet of such borings have in this way been entered in our books. Sheets of horizontal sections on a large scale are likewise issued to form, with the maps and explanations, a compendium of the geological structure of each large district.

Another feature of the work of the Survey is the collection of specimens of the rocks and fossils of each tract of country as it is surveyed. Since my previous Report to this Section of the British Association, we have collected 1011 specimens of rocks, and 7500 fossils. These are named and exhibited, as far as the present accommodation will permit, in the Museum of Science and Art at Edinburgh.

The work of the Geological Survey is carried on, as I have said, under the guidance of its Director-General, Sir Roderick Murchison, a name which has long been a household word at the meetings of the British Association, and one to which I am sure you will permit me to make on this occasion more than a passing reference. While the Survey advances, as I have shown, steadily over the face of the country, unravelling piece by piece the complicated details of its geological structure, to Sir Roderick belongs the rare merit of having himself led the way, by sketching for us, boldly and clearly, the relations of the older rocks over more than half of the kingdom. Much must undoubtedly remain for future investigation, but his outline of the grand essential features of Highland geology will ever remain as a monument of his powers of close yet rapid observation and sagacious inference. At one time I had hoped that the Chair of this Section might be filled by him, and that we should be permitted to listen anew to his expositions of the rocks of his native country. There is no one among us who does not regret the absence of the familiar face and voice of the veteran of Siluria. We meet once more on Scottish ground, and for the first time we have not here with us the man who has laid a deeper, broader impress on Scottish geology than any other geologist either of past generations or of this. There is, however, on the present occasion, a special cause

for regret. Only within the last few months he founded a Chair of Geology in the University within whose walls we are now assembled—the first and only chair of the kind in Scotland. It would have been a fitting and grateful duty on the part of the University to welcome one of its most distinguished benefactors. I am well aware, indeed, that this Section-room is no place for the obtrusion of personal sentiments; yet I would fain be allowed to add in conclusion an expression of my own deep regret at the recent illness and consequent absence of one to whom, over and above the admiration which we all feel for his life-long labours and his personal character, many years of friendly intercourse have bound me by the closest ties of affection.

Fossiliferous Strata at Lochend near Edinburgh *By* D. Grieve.

The strata to which this notice refers are situated on the east side of the Loch, and appear in the Trap precipice, on which stand the ruins of the ancient Keep of the Logans of Restalrig. Although it was conjectured, it was not known, until Mr. Grieve found distinctive fossils in these strata, that the Carboniferous formation, so largely spread over the site of Edinburgh and its neighbourhood, extended so far to the eastward; and it would now appear that these form a continuity of the strata and shales found some years ago on the north side of the Calton Hill. They are of the *Lower* Carboniferous formation, and seem to be equivalents of the sandstones and shales of Burdiehouse on the south, and Wardie and Granton on the north and west of Edinburgh.

The fossils found by Mr. Grieve at Lochend he enumerates as follows:—Of Plants, Calamites of a large and well-marked species, a Lepidodendron and Lepidophyllum, with various Sphenopterites. Of Fishes, a beautiful specimen of the genus *Palæoniscus*; also scales, teeth, spines, and coprolites. Lastly, a Crustacean, *Cypris Scoto Burdigalensis*, or of an allied species.

It is to be regretted that the quarry from which the above fossils were obtained has now been obliterated in the course of agricultural improvements.

On the position of Organic Remains near Burntisland. *By* G. J. Grieve.

On "The Boulder Drift and Esker Hills of Ireland," and "On the position of Erratic Blocks in the Country." *By* Sir Richard Griffith, *Bart., F.R.S.*

Sir Richard commenced by giving a short description of his geological map, and mentioned that the direction of the mountain-ranges generally, as well as the strike of the strata, ranged from north-west to south-east. He stated that the position of Ireland with respect to Europe was further to the west into the Atlantic Ocean, and that on the west side were numerous deep bays, guarded by promontories composed of hard rocks, while on the east side the coast was only slightly indented on any part. He mentioned that the coast of Ireland all round was composed of mountains, while the interior was nearly flat, and that the rock of that plain was altogether composed of Carboniferous limestone. He stated that a line drawn from Sligo Bay on the west to Drogheda Bay on the east, would form the northern boundary of the great plain, while the southern boundary might be shown by a line drawn from Galway Bay on the west to Dublin Bay on the east, comprehending an area of 5000 square miles. This large district was divided into nearly two equal parts by the river Shannon, whose source was near Lough Allen, in the county of Cavan, elevated 160 feet above the level of the sea, while the length of its course to the sea, at Limerick, was 140 miles, giving an average fall of 1 foot 2 inches in a mile; and he further stated that this fall was not equally distributed, as between Limerick and Kildare, a distance of 12 miles, was a fall of 98 feet, showing that from the distance of 128 miles between Lough Allen and Killaloe, there was an average fall of less than 6 inches in a mile. The great centre plain, already described as containing 5000 square miles, contained 1,000,000 acres of bogs, each of which was surrounded by drift resting on the top of the

Carboniferous limestone, and it usually presented an undulating surface which occasionally affected the form of elongated elliptical hills, which usually ran parallel to each other. This fact was especially exemplified by Clew Bay, situated on the west coast, in which were upwards of 300 islands, the surface of which was composed of boulder-drift resting on Carboniferous limestone. He mentioned that at least on the eastern the boulder drift had a thickness of about 100 feet, but probably was much thicker towards the west. He described the boulder-drift as composed of a base of sandy or gravelly clay, which contained numerous rolled masses, huddled together in a confused manner without reference to size, and that their dimensions ranged between those of a small egg and two or three cubic feet in diameter. He next adverted to those remarkable ranges of hill, which varied in height above the surface of the boulder-drift from twenty to sixty feet, the ascent being usually about thirty degrees on the west side, but less steep on the east. These Esker hills were very numerous in the midland plain, especially in the counties of Mayo, Galway, and Roscommon, on the west side of the Shannon, and of the King's County and Westmeath on the east. Their general direction was from west to east; and one great Esker, which extended from west to east from the county of Galway to Westmeath, was used as the post road from Dublin to Galway, for a length of 30 miles. This great Esker crossed the river Shannon at Athlone, and was subsequently cut through by it, exhibiting a great shoal at the present time, on which the old bridge of Athlone was built. On the western side, about 50 feet above the river, an ancient fort had been erected to defend the passage, and this fort still remained in perfect preservation. The town of Athlone was also built on the east side of it, and extended from thence nearly 20 miles. Fifteen miles to the south of Athlone, the river Shannon was crossed again by another Esker, also running from west to east, and in this place the Esker presented very steep acclivities on either side. He last described a very remarkable Esker called the "Horseshoe," from its form, the north arm of which running eastward extended for 10 miles, whilst the southern extended 8 miles, leaving an opening of 8 miles, with the town of Clara in the centre. The slopes of these horseshoe Eskers on the west side were steep, having an angle of about 30°, while on the outer side the slope was only from 10 to 15°. Having mentioned that in many cases Eskers were observed, particularly to the west of Athlone, having a north and south direction, he gave it as his opinion that the Eskers were deposited on the top of the boulder-drift at a subsequent period, and that the materials, which were similar to the boulder-drift, with the exception of the admixture of sandy clay matter, were deposited from currents and waves in a shallow troubled sea, and possibly did not owe their existence to glacial action. Sir Richard next directed the attention of the Section to the occurrence of large erratic blocks, totally unconnected with the gravel, which were found resting on the surface throughout the entire district, from Galway Bay in an eastern and southern direction, passing over the summits of the Slieve-bloom mountains, near Roscrea, and extending from thence through the King's and Queen's counties. These blocks were all composed of a peculiar porphyritic granite from the district situated to the north of Galway Bay. This granite was composed of red and white felspar, grey quartz and black mica, and contained numerous crystals of red felspar, which rendered the appearance so peculiar that no doubt could be entertained that the granite blocks above mentioned were derived from the Galway district.

These blocks are usually angular though occasionally slightly rounded. One, whose dimensions was 10′ by 5′ by 3′, equal to 4 tons in weight, is described by Mr. Joseph O'Kelly, of the Geological Survey of Ireland, as resting on Lower Silurian ground, 10 miles to the north of the Town of Roscrea, at an elevation exceeding 1000 feet above the sea; and his colleague, Mr. G. Henry Kinahan, the senior geologist, found great numbers of these blocks scattered over the limestone plain, in the neighbourhood of Athenry, to the east of Galway. He likewise described large blocks of the same granite in the valley of Glensascaul, at the western base of the Slieve-bloom mountains, the dimensions of one of which was 12′ by 10′ by 11′, equal to 110 in weight, and others whose weight varied from 35 to 48 tons.

Sir Richard next alluded to another drift of erratic blocks, which took a course

from south to north, crossing the Curlew and Ox mountains in the county of Sligo, the direction of each being from north-east to south-west.

The Curlew mountains consist of brown sandstone belonging to the Upper Silurian series, the surface being elevated above 800 feet above the level of the sea. Descending the mountains to the north, to the limestone valley of Tobercurry, which occurs between them and the Ox mountains, we find the surface with very large boulders of brown sandstone; and continuing to the northward the ascent of the Ox mountains, which are composed of mica-slate, we find the boulders of brown sandstone continued, though diminished in size. On reaching the height of 450 feet above the limestone valley, we meet with limestone Eskers having an east and west direction, crossing the mountain valley at right angles, and on top of which numerous angular blocks of mica-slate rest; but the mica-slate is intermixed with gravel, which is composed altogether of clean rolled masses of Carboniferous limestone. Milan Mountain, one of the Ox range, the summit of which is elevated to the height of 1446 feet above the sea, is composed of granite, forming part of a large protrusion through the mica-slate, which is metamorphosed near the contact.

This granite is large-grained, and is composed of red and white felspar, grey quartz, and black mica, but without any crystals of red felspar such as occur in the Galway granite.

Descending the mountains to the north, we reach the Easky Lough, elevated 706 feet above the sea. Here the granite is bounded by mica-slate, which continues to the base of the declivity, and we find the surface covered by blocks of granite; and continuing still further across the limestone plain to the sea-coast, to Easky village, a distance of 8 miles, we find the surface also covered by very large blocks of granite; and one in particular, which is situated within half a mile of the sea-shore, and near to Easky village, was, on measurement, found to contain 1360 cubic feet, equal to 100 tons in weight.

Similar granite blocks occur on the surface of the whole line of the north coast of Sligo and Mayo, all of which are similar in composition to the Easky granite, as well as to that which occurs on the summit of the Ox mountains to the west of Easky Lough as far as the town of Foxford; and no doubt can be entertained that such must have been transported by ice.

On the Agency of the Alternate Elevation and Subsidence of the Land in the formation of Boulder-clays and Glaciers, and the Excavation of Valleys and Bays. By the Rev. JOHN GUNN.

Mr. Gunn briefly recapitulated the contents of a paper which he read at the Meeting of the British Association at Liverpool, to the effect that boulder-clays were deposited in a temperate rather than in a glacial period, inasmuch as the area of the sea was increased by the subsidence of the land; the perpetual snow-line must have been lowered, masses of ice disengaged, icebergs set floating and the boulder-clays formed; that the glacial epoch was due to the elevation of mountain-ranges and consequent glaciers. He proceeded to show that, in some instances which he specified, the agency of the alternate elevation and depression of the land in scooping out valleys and gorges where there was no evidence of ice action might be traced; that such effects were due to the action of shallow seas, either while clearing off, or while gathering over the surface of the land, and cutting out with its incessant surge water-worn channels and inland bays. He stated, in conclusion, his opinion that there was no occasion to invoke any additional causes of change of climature besides those which were known to exist; but the question which remains to be solved is, to what cause are these alternate oscillations of level due?

Professor HARKNESS, F.R.S., F.G.S., exhibited one of the earliest forms of Trilobites.

On the Age of the Felstones and Conglomerates of the Pentland Hills. By JOHN HENDERSON, *F.G.S.E., read by* D. J. BROWN, *F.G.S.E.*

This paper was illustrated by two sections, and specimens of rocks and fossils were exhibited.

The felstones of the Pentland Hills, with their contemporaneous conglomerates and sandstones, have hitherto been considered of Old Red Sandstone age, by Murchison, M^cLaren, Geikie, and others. Having frequently examined the various exposed sections throughout the district, and from the evidence collected, the author endeavoured to prove that some of these felstones, conglomerates, and sandstones are as new as the upper portion of the Lower Carboniferous.

The first section referred to may be seen on the north-west side of the hills at Clubbiedean, where beds of Carboniferous sandstone and shales, containing *Sphenopteris affinis* and other well-known Carboniferous fossils, are ruptured, tilted and hardened by the intrusion of the felstones; and these intrusive felstones enclose fragments of hardened shales and limestones, yielding encrinites belonging to these beds, showing conclusively that these felstones are of a more recent age than the overlying carboniferous. The other section referred to occurs about four miles further to the south-west, at Bevelau and Habbies How, where these supposed Old Red Sandstones and Conglomerates may be seen resting on the upturned edges of the Silurian rocks. In these Silurian rocks the author detected a number of felstone dykes, one of which is about 30 feet broad, and may be traced up the face of Harehill, a distance of about 300 feet, where it is covered by horizontal beds of sandstone—the supposed Old Red—which it does not penetrate, while in the valley to the south of Harehill some limestone pebbles were found enclosed in the conglomerates, which contain fossils evidently of Carboniferous age, such as *Serpula parallela*, &c., showing that these sandstones and conglomerates cannot be of Old Red age as hitherto supposed.

Now, when it is considered that the Lower Carboniferous rocks in this district are everywhere broken up by intrusive felstones and greenstones, while the sandstones and conglomerates of Harehill and the Cairnhills remain almost untouched by igneous action, and lying nearly horizontal and undisturbed, the natural conclusion arrived at is, that these supposed Old Red Sandstones were not deposited until after the igneous forces which have disturbed the Lower Carboniferous in this district were nearly exhausted; and the whole evidence clearly shows that these supposed Old Red Sandstones, Conglomerates, and Felstones of this part of the Pentland Hills must at least be as recent as the upper part of the Lower Carboniferous.

On the relative ages of the Granitic, Plutonic, and Volcanic Rocks of the Mourne Mountains and Slieve Croob, Co. Down, Ireland. By Professor EDWARD HULL, *M.A., F.R.S., F.G.S., and* WILLIAM A. TRAILL, *B.A., of the Geological Survey of Ireland. (Communicated with the sanction of the Director-General of the Geological Survey.)*

Having referred to the bold and interesting physical features of the district, which in some respects resemble those of Arran, and which had already been objects of investigation by Griffith *, Berger †, and Bryce ‡, the authors observed that there were, as in Arran itself, two varieties of granite. These had been shown by the Rev. Professor Haughton § to differ in composition; the granite of Slieve Croob (consisting of quartz, orthoclase and mica) being a "soda granite," and that of Mourne (consisting of quartz, orthoclase, albite, and mica) being a "potash granite." Dr. Bryce had expressed an opinion that these two granites belong to different epochs ||.

* Geological Map of Ireland, 1839.

† "On the Geological features of the North-Eastern Counties of Ireland," by J. F. Berger, M.D., Trans. Geol. Soc. Lond. 1st ser. vol. i.

‡ "On the Geological Structure of the Counties of Down and Antrim," by James Bryce, LL.D., Rep. Brit. Assoc. 1852, p. 42.

§ Quart. Journ. Geol. Soc. Lond. vol. xii. p. 188, and xiv. p. 300.

|| *Supra cit.*

The relative and (as far as possible) the actual ages of these granites still remained to be determined, and in the absence of stratified deposits newer than the Lower Silurian in immediate contact with the granites themselves, the authors believed that conclusions might be safely arrived at by considerations connected with the basaltic and felspathic dykes by which the rocks had on several occasions been invaded.

They had arrived at the conclusion that the granite of Mourne was more recent than that of Slieve Croob by a long interval of geological time; the former being of Upper Palæozoic, the latter of, perhaps, Mesozoic age. These general conclusions were supported by the following considerations.

The granite of Mourne at its margin in some places passes into quartziferous porphyry, and sends offshoots of this rock in the form of dykes into the surrounding Silurian strata, as may be very clearly determined by several examples in the vicinity of Newcastle. Hence the authors inferred that the dykes of quartz-porphyry and felstone which traverse the granite of Slieve Croob might be referred to the age of the newer granite of Mourne; and thus the greater antiquity of the Slieve Croob granite might be determined.

Trap-dykes—The trap-rocks of the district were classed mineralogically as follows:—(*a*) Quartz-porphyries and highly silicated felstones. (*b*) Diorites. (*c*) Basalts or Dolerites of two ages.

Considered with reference to relative ages of formation, the following was the order of succession, in the ascending series.

(1) *Older Basalts and Dolerite Dykes.*—These form by far the most numerous of all the trap-rocks of the district, occurring in great numbers along the coast south of Newcastle, and amongst the interior mountains, as at Slieve Muck; they are also unquestionably the oldest of all the trap-rocks of the district.

Their age, with reference to the granite of Mourne, was placed beyond question by a large number of examples in which these dykes, after traversing the Silurian rocks, are abruptly terminated at the margin of the granite; they are therefore older than the granite itself*. These older basalts were found to traverse the Silurian rocks in well-formed dykes within vertical (or nearly vertical) walls, and are generally fine-grained, of dark green colour, undistinguishable from those of newer Tertiary age. Sliced specimens showed under the microscope the composition to be augite, triclinic felspar, and titano-ferrite.

(2) The next in order of age are the quartz-porphyries and felstones, which (as already stated) branch off from the main mass of the Mourne granite, and are unquestionably of the same age as the granite itself, and often strongly resemble it in its more compact form. Dykes of these rocks are also found traversing the older granite of Slieve Croob. They consist of a felspathic base with crystals of felspar, grains and crystals of quartz, and sometimes mica or hornblende, as accessories, and in small quantities.

(3) The Diorite dykes are few in number, the finest example occurring at Rostrevor. It consists of a crystalline granular aggregate of reddish felspar and hornblende well developed, and traverses the older basaltic dykes; but is, they believe, older than the granite of Mourne. It is therefore referable to some intermediate period.

(4) Besides the older basaltic dykes, which are cut off by the granite, there are a few which traverse both the Silurian rocks and the granite of Mourne itself. These are therefore newer than those previously described; and as they appear to be connected with those which are found traversing the Cretaceous rocks in Co. Antrim, the authors consider them to be of Miocene age.

In general aspect there is no decided difference between the older and newer basaltic dykes; they have all the external appearance of the Tertiary dykes, which abound along the margin of the basaltic plateau of Antrim, and in the West of Scotland; and had it not been for their relations with the granite of Mourne, they might have all been included in the same category.

It might have been supposed that microscopical examination would show some

* Sir Richard Griffith has informed one of the authors that he was already aware of this fact, but had not published his observations. Some of these dykes are represented on his Geological Map of Ireland.

distinction in the basalts of these geological ages; but recent investigations by Zirkel, D. Forbes, Allport, and others tend to show that there is no criterion of age amongst the constituents of basalt, dolerite, or melaphyre; and the presence of olivine, once supposed to be distinctive of Tertiary basalts, has been detected amongst those even of Carboniferous age *.

Age of the Older Basalt.—The geological age of these older basalts can only be relatively determined. They are newer than the Lower Carboniferous rocks, which they are seen to traverse at Cranfield Point and Carlingford. Recollecting the abundant evidences of contemporaneous volcanic action which the Carboniferous rocks of Scotland and portions of central England present, the authors are disposed to refer these older basalts to the Upper Carboniferous period itself; and having regard to the prodigious number of these dykes traversing the rocks at intervals along the coast from Dundrum Bay to Carlingford Bay, they suggest the former existence of one or more volcanic vents in their vicinity during later Carboniferous times; such a volcanic focus as is inferred to have existed in the vicinity of Carlingford by Professor Haughton †.

Sequence of Granite, Plutonic, and Volcanic rocks in the Mourne district.—The following may be regarded as the order of succession of these rocks with their approximate ages in the district north of Carlingford Bay, all being more recent than the age of the "Caradoc" or "Bala" beds of the Silurian epoch. Commencing with the oldest, we have:—

(*a*) Metamorphic granite of Slieve Croob, Castlewellan, and Newry. *Pre-Carboniferous*, therefore *Palæozoic.*

(*b*) Older basaltic dykes of Mourne and Carlingford. *Upper Carboniferous.*

(*c*) Diorite Dykes. *Later than the Carboniferous.*

(*d*) 1. Granite of Mourne .... } Post Carboniferous ‡.
2. Felstone and porphyry dykes penetrating the granite of Slieve Croob and the older basaltic dykes .... }

(*e*) Newer Basalts of Miocene (Tertiary) age.

Judging by the comparative scarceness of the newer Tertiary dykes in the district of Mourne, the authors drew the conclusion, that it may be considered as the southern limit of the region affected by the volcanic outburst of the Miocene period, which so powerfully affected the district lying to the north-east of Ireland and extending into the Inner Hebrides; while on the other hand it was the seat of active volcanic energy during an earlier period, which in all probability may be identified with the Upper Carboniferous, or that of the Upper Coal-measures of England.

On the Coal-beds of Panama, in reference mainly to their Economic Importance.
By the Rev. Dr. Hume.

On the Silurian Rocks of the Counties of Roxburgh and Selkirk.
By Charles Lapworth *and* James Wilson.

The authors gave a short summary of what they had already accomplished on the investigation of these strata, which they held fell naturally into five great divisions in this district. These divisions they had named respectively,

1. The Hawick Rocks,
2. The Selkirk Rocks,
3. The Moffat Series,
4. The Gala Group,
5. The Riccarton Beds,

after the places where they are best developed.

* Mr. S. Allport, 'Geological Magazine,' vol. vi. p. 115.

† Quart. Journ. Geol. Soc. vol. xii. p. 193.

‡ Professor Harkness suggests that the eruption of the granite of Mourne may be referred to the period which intervened between the depositon of the Carboniferous and Permian strata, a period of great duration; and he thinks there is a strong resemblance between the granite of Mourne and that of Kirkcudbrightshire, which is referable to this period. Against this view it is to be observed that it would bring the older basaltic dykes close upon the heels of the Mourne granite, which seems rather improbable.

The Hawick and Selkirk rocks fill up all the central portion of the district described, extending from near Selkirk to Mosspaul. They form the great anticline of the South Scottish Silurians, and appear to be the lowest rocks exhibited. They contain a few fossils, such as *Annelida, Protichnites, Protovirgularia, Phyllopoda.*

The Moffat series is remarkable for the bed (or beds) of anthracitic shale which it contains, and which is famous for the large number of Graptolites found in it. The Moffat series, with its black shale-band, makes its appearance twice in the district described,—1st, in the country between Selkirk and Melrose; 2nd, in the region of the Moorfoot Hills; these beds yield fossils of the genera *Dicellograpsus, Dicranograpsus, Cladograpsus, Climacograpsus, Discinocaris, Peltocaris, Siphonotreta, Lingula.*

The Gala group lies in the syncline formed by these two appearances of the Moffat series, and consists of grits, sandstones, shales, and conglomerates, that imbed a Middle Silurian fauna, including *Monograpsus, Diplograpsus, Retiolites, Dictyonema, Aptychopsis, Ceratiocaris, Dictyocaris, Orthoceras.*

The Riccarton beds fill up all the Silurian country to the south of a line drawn from Kirkcudbright to Jedburgh. The fossils are Upper Silurian, and include *Cyrtograpsus, Ptilograpsus, Theca, Orthoceras, Ceratiocaris, Aptychopsis, Pterygotus, Rhynchonella.*

The authors believe that the anthracitic bed of Moffat is of Bala age, that the Gala group contains strata of both Caradoc and Llandovery age, and that the Riccarton beds should be classed with the Wenlock or Lower Ludlow.

On the Graptolites of the Gala Group. By CHARLES LAPWORTH.

The Graptolites found in the Gala group form an assemblage quite distinct from that afforded by the Moffat series. The species known at present are:—

1. Diplograpsus bullatus (*Salt.*).
2. —— palmeus (*Barr.*).
3. Retiolites Geinitzianus (*Barr.*).
4. —— obesus (n. sp.).
5. Graptolites Sedgwickii (*M'Coy*).
6. —— sagittarius (*His.*).
7. —— Beckii (*Barr.*).
8. —— Nilssoni (*Barr.*).
9. —— Halli (*Barr.*),
10. —— Griestonensis (*Nicol*).
11. Graptolites Salteri (*Geinitz*).
12. —— fimbriatus (*Nich.*).
13. —— priodon (*Bronn*).
14. —— colonus (*Barr.*).
15. —— socialis (n. sp.).
16. —— turriculatus (*Barr.*).
17. —— gemmatus (*Barr.*).
18. Rastrites Linnæi (*Barr.*).
19. —— maximus (*Carr.*).
20. Dictyonema, sp.

Two of these species, *i. e. Retiolites obesus* and *Graptolites socialis*, are new to science.

In *Retiolites obesus* the frond is diprionidian, ensiform, or elongate-elliptical in form, with a length of $1\frac{1}{2}$ inch in the largest specimens, to a breadth of more than $\frac{1}{3}$ of an inch. The meshes on the central surface are hexagonal, $\frac{1}{50}$ of an inch in diameter. Round the inner margin of the frond runs a series of large subquadrangular meshes, which forms a peculiar and characteristic braiding, distinguishing this form at once from all other species of the same genus. These meshes show the place of the cellules, which are from 22 to 24 to the inch.

Graptolites socialis is monoprionidian, flagelliform, $\frac{1}{30}$ of an inch in width and less than 2 inches in length. The cellules are formed after the type of those of *Graptolites Beckii* (Barr.). They are arranged along the concave side of the stipe, from 34 to 44 to the inch.

This species is found in great numbers in some of the Gala beds.

On the Origin of Volcanoes. By P. W. STUART MENTEATH.

The author's views are briefly stated in 'Scientific Opinion' for April 7, 1869. Since that date, M. Fouqué in France, and Peschel in Germany, had published very similar views, although M. Fouqué, until lately, opposed all chemical theories of the origin of volcanoes. The author, therefore, ventured to bring forward his theory more in detail, and he believed that if chemical geology were more gene-

rally studied, that theory would not appear startling. He had considered the objections of Bischof and others to chemical theories, and he believed that they did not hit the explanation he proposed. That explanation attributes the force of volcanic action to solar energy, stored up in rocks by buried organic matter—this organic matter either existing in rocks as carbon and carbonaceous compounds, or represented by sulphides and other substances, produced by the reducing-action of organic matter. Volcanoes, as has been said of steam-engines, are worked by "the light of other days." Starting from the five groups of well-preserved extinct volcanoes in Spain and Portugal, proceeding to consider the volcanoes of the Mediterranean basin, and finally volcanoes in general, the author concluded that, as had been pointed out by Sterry Hunt, volcanoes, as a rule, lie on or at the borders of much sedimentary rock; and the exceptions to this rule he considered to be explicable in conformity with his theory. These sedimentary rocks, especially in the Mediterranean basin and under the volcanoes of Catalonia, could be said to contain much organic matter. Next, he examined the alleged fact of the occurrence of volcanoes along great lines of fissure, and concluded that their occurrence in lines was due to their connexion with the sea, as well as with lines of sedimentary deposition. The author believes that the sometimes alleged identity of volcanic rocks was a statement either misleading or meaningless, and that the composition of volcanic rocks was just what we should expect, if they were formed from masses of sedimentary rocks, in presence of sea-water. Proceeding to the consideration of the results of Fouqué, Deville, Daubeny, and others, regarding the gaseous products of volcanoes, he showed that these afforded striking evidence that a mixture of gases, similar to that evolved in gasworks, was oxidated in volcanoes with production of great heat. To this heat, and to the burning of separated carbon, sulphur, and probably iron, he attributed the high temperature present in some lava on its appearance in the air. From the researches of Sorby, Zirkel, Daubrée, Delesse, Stoppani, and others on the subject of lavas, he concluded that these were formed at moderate temperatures, and only exceptionally fused by the great heat produced in the crater. The enormous amount of heat assumed to be present in volcanic action was, in the author's opinion, in great part mythical, and what was actually ascertained could be explained by the nature of the substances oxidating in the earth and burning at the crater. As to the introduction of air and water, he referred to the penetration of sea-water at Cephalonia, to the researches of Delesse, to the Catalan *trompe,* and to the fact that sea-water dissolves much oxygen; while the nitrogen evolved, in volcanic areas and elsewhere, is usually either pure or accompanied by less oxygen than would compose atmospheric air. He then pointed out that the amount of carbon found in rocks might be adequate to produce all the heat required, if we assumed the rocks to have been rapidly deposited; whereas, if they had been slowly deposited, the amount of carbon now existing in them could only be a remaining fraction of that they formerly contained, the rest having been evolved as carbonic acid. If he were to reject geological time, as some have done, he might assume that the volcanic heat to be accounted for was just as much as the average amount of carbon was adequate to supply. After attributing the origin of the vast amount of buried carbon now in rocks to buried carbon in former rocks, and remarking that it must have passed very gradually through the atmosphere, he discussed some correlated processes in nature which would keep volcanic action roughly uniform, the sun-force continually passing through organic matter into volcanic heat. He confined himself chiefly to volcanic action proper, as that was generally considered the best evidence of the original-heat theory; but he considered that such general internal heat as had been ascertained might be attributed to the distribution of volcanic heat by water, to general oxidation of the carbon almost universal in rocks, to friction as shown by Bianconi, and finally, to the electric currents ascertained to exist in the earth, and to be probably produced in great part by the sun.

The paper was illustrated by sketches taken by the writer in the Two Sicilies, the Greek Isles, Catalonia, &c., also by some curious specimens of metamorphosed glass, which he had found while excavating for antiquities in Ischia.

Further Experiments and Remarks on Contortion of Rocks. *By* L. C. Miall.

After recapitulating the results of some experiments on contortion of mountain limestone brought before the Association at Exeter, the author went on to state that with improved apparatus he had extended his experiments to various substances. Limestone appeared to be exceedingly plastic when long subjected to forces of low intensity. Flagstones from the Coal-measures with a certain amount of elasticity possessed little power of permanent deflection. This negative result is, however, to be checked by observation of cases of accidental flexure of flagstones. Examples were cited of these rocks which had yielded to strains, and had become permanently bent. Plaster of Paris the author finds remarkably plastic, and a long series of experiments with dry slabs shows that it can be bent and twisted indefinitely. Slates had also been tested, but with quite inconspicuous results. A considerable elasticity was found to characterize good slate, with a quite inappreciable plasticity. The author had obtained striking examples of artificial contortion by imbedding laminæ of various rocks in pitch. These results were applied to the very sharp flexures sometimes seen in hard strata lying in beds of shale. Cases of quite superficial contortion were quoted, and from numerous instances of marked undulations in strata which were underlain by horizontal and undisturbed layers, it was inferred that many contortions extend only to trifling depths. A case of contortion traceable to the removal of part of a hill-side by a landslip was referred to as showing that flexures on a considerable scale may be of quite recent origin. In conclusion, some remarks were made on the general theory of contortions at the surface of the earth.

On the so-called Hyoid plate of the Asterolepis of the Old Red Sandstone. *By* John Miller, *F.G.S.*

In the Number of the 'Geological Journal' for August 1869, the author published a letter, stating that he had obtained two specimens of the *Asterolepis* from the great flag-deposits of Caithness, which showed clearly and distinctly that what had hitherto been considered to be the hyoid plate was not a hyoid plate at all, but was in reality the dorsal plate of the *Asterolepis*, fitting on immediately behind the cranial buckler, pretty much in the same way as the dorsal plate of the *Coccosteus* fitted on behind its head-plates. He stated that he would endeavour to lay his specimens before the Geological Society of London as soon as possible; however, circumstances have prevented this. The specimens referred to were exhibited on the present occasion, in fulfilment of the pledge given to the Geological Society.

It is right to premise that from the time these plates were first made known to geologists by Asmus and Eichwald in Russia, and by Sir Roderick Murchison and Agassiz in the west of Europe, they have been regarded in Russia and in this country as hyoid plates, down to the period of the publication by Pander of his works on the Devonian system of Russia, in which he stated his opinion that they would turn out to be dorsal plates when more complete fossils turned up. This opinion was shared in by several of our most eminent palæontologists, and amongst others by Mr. Peach, who has long worked in the *Astrolepis*-beds of Caithness, and is well acquainted with the geology of that county.

In his description of the *Asterolepis*, Hugh Miller says ('Footprints of the Creator,' p. 85 of the edition of 1861):—"That space comprised within the arch of the lower jaws, in which the hyoid-bone and branchiostegous rays of the osseous fishes occur, was filled by a single plate of great size and strength, and of singular form" (*ibid.* fig. 40).

And again, at p. 87 (*ibid.*):—"The two angular terminations of the hyoidal plate (*a, a*, fig. 40) were received, laterally and posteriorly, into angular grooves in a massive bone of very peculiar shape (fig. 42), of which the tubercled portion (*a, a*) seems to have swept forwards in the line of the lower jaw." In these short extracts Hugh Miller, with his characteristic unmistakable clearness, states the generally received opinion regarding the position of the so-called hyoid plate; and

it was the author's object to show that the generally received opinion on the subject is a mistake, and that the plate in question is in reality a true dorsal plate, fitting on immediately behind the cranial buckler or head-plates, and that those naturalists who had previously supposed that this would ultimately prove to be its right position, from Pander down to Peach, were found to have been quite correct in their opinion. The author exhibited a sketch of his best specimen, in which was seen the upper surface of the cranial buckler, described by Hugh Miller, with the dorsal plate, in its true position, and attached to the cranial buckler by two "massive bones of very peculiar shape," alluded to in the quotation above.

Conservation of Boulders. *By* D. Milne-Home, *F.R.S.E.*

Professor Geikie having stated that the next subject to be brought under the notice of the Section was the conservation of remarkable boulders, begged to mention that the Sectional Committee had passed a resolution, intimating their sense of the importance of the subject, and recommending that the British Association should appoint a Committee, with a grant of money at its disposal, to endeavour to discover the position of remarkable boulders in any part of the United Kingdom, and also to have them preserved. The Royal Society of Edinburgh had already taken steps for these objects as regards Scotland; and it would be well to have the movement extended so as to embrace England and Ireland; and the two Committees would no doubt cooperate, as far as Scotland was concerned. He then called on Mr. Milne-Home, the Chairman of the Committee of the Royal Society of Edinburgh, to explain more particularly the objects contemplated, and the measures which might be taken to carry them out.

Mr. Milne-Home said that his attention to the subject had first been awakened by an article in 'Nature,' from the pen of their President, Professor Geikie, giving an account of proceedings which had been commenced in Switzerland for the preservation of remarkable boulders. Being acquainted with Professor Favre, of Geneva, he had learned from him that the movement embraced Dauphiny and other provinces in the South of France, and that the effect had been to create a strong popular sympathy in the object. Following this precedent, he had induced the Royal Society of Edinburgh to appoint a Committee, whose duty it was to send circulars to all the parishes in Scotland, with the view of ascertaining the existence in them of any boulders remarkable for size or for other features. Many questions of much geological interest could be solved by ascertaining the nature of the rocks composing boulders, and studying their shapes, in order to deduce conclusions as to the transporting agent. These boulders, however, were fast disappearing, sometimes owing to agricultural improvements, and sometimes affording, when broken up, materials for building or for road-metal. It was therefore important to discover the localities where any remarkable boulders existed, in order that they might be examined by those who took an interest in such speculations, and in order also to have them preserved. He had reason to believe that the proprietors and tenants of the lands on which such boulders might be situated would willingly accede to any application which might be made to them by scientific societies to preserve them. He was sure that, were this Section to express views favourable to that object, great good would result.

Further Remarks on the Denudation of the Bath Oolite. *By* W. S. Mitchell.

On Geological Systems and Endemic Disease. *By* Dr. Moffat.

The author remarked that the district in which he lived consisted geologically of the Carboniferous and of the New Red or Cheshire sandstone systems; that the inhabitants of the former were engaged in mining and agriculture, and those of the latter in agriculture chiefly. Anæmia, with goitre, was very prevalent among those on the Carboniferous system, while it was almost unknown among those of the Cheshire sandstone, and phthisis was also more prevalent among the

former than the latter. As anæmia was a state in which there was a deficiency in the oxide of iron in the blood, he was led to examine chemically the relative composition of wheat grown upon a soil of Cheshire sandstone, carboniferous limestone, millstone grit, and a transition soil between the Cheshire sandstone and the grit; and the analysis showed that wheat grown upon Cheshire sandstone yielded the largest quantity of ash, and that it contained a much larger quantity of phosphoric acid and oxide of iron than that grown upon the other formations. He calculated that a dweller on the Cheshire sandstone who consumed 1 lb. of wheat daily, grown upon the latter formation, took in nearly five grains more per day of oxide of iron than one who dwelt on the Carboniferous system who did the same. The analysis showed also that the wheat grown upon the Carboniferous system was deficient in phosphates or nutritive salts; and one who consumed a pound of Cheshire wheat per day took in nine grains more of phosphoric acid than one who took one pound of wheat grown upon the Carboniferous system. He had endeavoured to ascertain whether the bread of those who dwelt upon the two systems was relatively as deficient in these important nutritive elements as the wheat grown upon them. He had collected twenty samples of bread used by twenty different families living upon each system, and analysis afforded results as conclusive as the examination of the wheat. The deficiency of the nutritive salts in the bread compared with those in the wheat was very remarkable; and it was no doubt owing to the removal of the bran from the flour with which the bread was made. The writer then gave some statistics as to the diseases prevalent in the counties of Chester, Flint, and Denbigh, and stated that the practical deductions to be drawn from the inquiry were, that all young persons living on a Carboniferous formation having symptoms of incipient goitre and anæmia, ought to be moved to a soil upon Red Sandstone, and persons of strumous habit ought to reside upon sandstone at an elevation of at least 800 or 1000 feet above the sea; and that both classes of persons should live upon food, both animal and farinaceous, which contained the maximum quantity of oxide of iron and the phosphates or nutritive salts. Medical men could not too much impress upon the minds of the public the importance of using flour made from the whole of the wheat, or "whole grain."

On the Systematic Position of Sivatherium giganteum, *Faulc. and Caut**. *By* Dr. James Murie, *F.G.S., F.L.S., &c.*

Among the fossil fauna discovered in the Sewalik Hills, the *Sivatherium*, one of these, as attested by its remains, must have attained the size of a full-grown elephant. It appears, however, to have been a ruminant, in some respects Deer-like, in others more resembling the Antelope. Still stranger, it seems to have had some characteristic features of Pachyderms—the Tapir, for example. After a careful review of the statements and deductions that have been made upon the *Sivatherium*, the author went on to show that it belonged to those radical forms which by some may be regarded as one of the progenitors of diverse herbivorous groups. The fossil bones studied by him are those contained in the British Museum. There is also a remarkable fragment in the Edinburgh University Museum. The points which he regarded as affording a safe basis of the affinities of this curious animal are:—1. The form and structure of the horns; 2. the shape of the bones of the face; 3. the nature of the teeth; 4. the formation of the basis of the skull; and 5. other peculiarities of the neck, chest, and limb-bones. The *Sivatherium*, according to him, is unlike all other living ruminants but one, the Prongbuck, from the fact of its having had hollow horns, evidently subject to shedding. It differs thus from Deer, whose solid horns annually drop off, and from the Antelope tribe, Sheep, and Oxen, whose hollow horns are persistent. Save one living form, the Saiga, no recent ruminant possesses, as did the *Sivatherium*, a muzzle resembling in several ways the proboscis of the Tapirs and Elephants. The dentition partook of the characters of the ancient *Elasmotherium*, &c. The

* This paper has been published *in extenso* in the Geol. Mag., October 1871, accompanied by two double plates of the restoration of the skeleton and a representation of the animal, ♂, ♀ *et juv.* Therein references to the several authorities &c. will be found.

basis and hind end of the skull is typical of oxen. The sternum, portion of the spine, and general strength of the limb-bones show configurations allying it with the Bovidæ. Other features of the legs hint an affinity to the Camel. On the strength of his own researches, and those of Mr. Bartlett and Dr. Canfield, the author is inclined to place the *Sivatherium* in the family Antilocapridæ ; Drs. Sclater and Gray having raised the Prongbuck to a group equivalent to the Cervidæ and Antilopidæ, chiefly from the singular fact of its horns being hollow and periodically deciduous. The great Indian *Sivatherium* he considers might as well be taken as the centre type of a family, the Sivatheridæ. He points out that radiating from it can be traced a differentiation of structure allying it to the ancient Bramotherium and Megacerops. Diversely, links lead through the Prongbuck towards the Deer, Giraffe, and Camel. On the other hand, configurations point undoubtedly to the Saiga; and there it is, as it were, split into lines directed towards the Antelope, the Sheep, and even the Pachyderms.

Additions to the list of Fossils and Localities of the Carboniferous Formation in and around Edinburgh. By C. W. Peach, *A.L.S.*

The author, after a few preliminary remarks, stated that he had found *Spirorbis carbonarius* rather plentiful at Burdiehouse, showing that the limestone there had been deposited in brackish water; *Estheria*, in Camstone quarry, in Arthur's Seat, plentiful; *Leia* in an ironstone nodule at Wardie, Professor R. Jones says, "the most northern locality at present known;" *Acanthodes Wardi* plentiful in the Parrot-coal at Loanhead, rare at the brickwork and No. 1 Pit and Shield Hill, Falkirk, and in the black-band and gas-coal at Auchenheath, Lesmahagow. In addition to the well-known *Pygopterus* of Wardie, he had got from Loanhead splendid specimens, with large and beautifully carved jaws and striated teeth, for which, should it prove new, he proposed to name it *P. elegans*. It is rare.

He next exhibited a portion of a splendid spine, beautifully tubercled, and covered as well with thorn-like hooks, differing from all figured by Agassiz. He exhibited other things, probably new; also a shagreen-covered fish; he had found it in several localities. As all were so imperfect he refrained from doing more than showing them to the members, so that any one knowing it might throw light on it.

He next exhibited and commented on a series of beautiful specimens of coal-field plants, consisting of large leaves and stem of *Cordaites borassifolia* ; *Calamites nodosus* in a splendid state, showing its pairs of branches, pinnæ, and leaves; from these he had been able to make nearly a complete restoration of the plant. The greatest prize was *Antholithes Pitcairniæ*, with its fruit Cardiocarpon attached, hanging gracefully by its swan-like stem; these, with many other interesting plants, he got in the blaes above the coal at Coach-road pit, near Falkirk.

He remarked that some of the jaws and portions of the fishes from the coal-fields retained their greasy nature, throwing off water when wetted like the chalk used by lithographers, and instantly drying, whilst the matrix in which they were enclosed remained wet.

On Hydro-Geology. By L'Abbé Richard.

On the Contents of a Hyæna's Den on the Great Doward, Whitchurch, Ross. By *the* Rev. W. S. Symonds, *F.G.S.*

The following is the order of deposition of materials in the Cave known as King Arthur's Cave.

1. Fallen débris containing Roman pottery and recent human bones.
2. Cave-earth No. 1, three feet thick. Flint flakes and a flint knife. Cores of chert and Silurian quartz rock. Teeth and jaws of *Felis spelæa*, *Ursus spelæus* and *Hyæna spelæa*, *Elephas primigenius*, *Rhinoceros tichorhinus*, *Equus fossilis*, *Megaceros hibernicus*, and *Cervus tarandus*.
3. Old river-bed of red sand and Wye pebbles from the Silurian rocks of Rhayader and Builth, three or four feet thick.

4. A thick floor of stalagmite, on which the river-bed rests.

5. Cave-earth No. 2. Several flint flakes, with abundant remains of Cave Lion, Hyæna, Rhinoceros, Mammoth (three sizes and ages), Irish Elks, Horse, Bison, and Reindeer.

The Wye now flows 300 feet below the ancient river-deposit of sand and pebbles.

In the lower cave-earth are associated the relics of ancient men and the extinct mammalia; and the author expressed his conviction that there are no better authenticated evidences of the antiquity of man in the records of cave-history.

On a New Fish-spine from the Lower Old Red Sandstone of Hay, Breconshire. By the Rev. W. S. Symonds, *F.G.S.*

This is a new Icthyodorulite now in the possession of the Earl of Enniskillen. It is described by Mr. Etheridge, of the School of Mines, under the name of *Onchus major*. It is the largest known spine from the Lower Old Red Sandstone.

The stratigraphical position of this Fish-spine was described to Mr. Symonds by Mr. John Thomas, C.E., of Hay, Brecon. It was found at Llidiart-y-Warn quarry, near Hay. The following is Mr. Thomas's account:—

"This fossil, with several others, was found by Mr. David Jones, of Hay, some three or four years ago, who, not knowing its value, left it to lie in his garden on a rockery. It is much weathered in consequence.

"All geologists acquainted with this district will recollect the fine section of Old Red as seen from the summit of the Black Mountains overlooking the Wye valley, between Hay and Glasbury. In 'Siluria,' p. 272, Sir Roderick Murchison has given a reduced copy of a section from the outcrop of the Carboniferous Limestone of the South Wales basin, across the Wye valley to the Upper Ludlow, in Radnorshire. The summit of the Black Mountain is occupied by chocolate-coloured sandstones, called by Mr. Symonds "Brownstones." Then, in descending, we have the red and green marls and the cornstones. The cornstones are very clearly defined and exposed on the slope of the hills from the Usk valley to Mousecastle, opposite Hay.

"About 200 feet below the cornstone-beds and at this point is Llidiart-y-Warn quarry, where the fossil was discovered. The beds in the quarry are formed of cornstone and very fine layers of whitish sandstone."

The structure of this Fish-spine is thus described by Mr. R. Etheridge, F.R.S.:—

"Form gently arcuated, of nearly equal diameter from base to apex, slightly compressed. *Posterior* free, concave, destitute of denticles. *Sides* apparently smooth, having no ridge or sulci, though it appears to have been originally delicately lined; base of spine round or obtuse, broad, smooth, or delicately striated; outer substance thick, internal axis large, and rugose on outer layer. Length 5 inches, breadth $\frac{1}{2}$ inch. Loc. Llidiart-y-Warn. Position. Cornstone of Lower Old Red Sandstone."

The anterior face of the spine is not seen; whether it is obtusely keeled or not is therefore unknown. The osseous structure and substance is well defined. The author doubts not that originally, or if we had the outer surface preserved, the spine was longitudinally ridged by deep, narrow sulci.

On the later Crag-Deposits of Norfolk and Suffolk.. By J. S. Taylor.

On the Stratified Rocks of Islay. By James Thomson, *F.G.S.*

The author described briefly the physical conditions of the island of Islay, then in detail the dip, strike, mineral character, and superposition of the stratified rocks, in the following order:—

1st. The calcareous deposits in the centre of the island, consisting of limestone, talcose shale, clay-slate, and interbedded quartzites, belong to the Lower Silurian group. The author remarked that although these calcareous deposits had not yet yielded identifiable organic remains, he did not despair, if they were properly in-

vestigated, of finding characteristic forms, which would enable us to place them with certainty as the equivalents of the Lower Silurian rocks, so well defined by Sir Roderick Murchison as occurring in Ross and Sutherlandshire.

2nd. The deposits on the eastern side of the island, and skirting the shore of the Sound of Islay from Ard-na-huamh on the north to Balleochreoch on the south, are of Cambrian age. Although the author has not seen the precise equivalents of the greenish-grey micaceous flags, with the felspathic partings found on the north side of Big-Free-Port Bay, on which we find sun-cracks, rain-prints, and what some suppose to be annelid tracks or burrows, yet they coincide so well with similar rocks, so very clearly shown by Sir Roderick Murchison as occurring in Sutherlandshire, where their relation to the inferior conglomerates is so ably traced, and also those described by the late Mr. Salter from the Longmynd beds in Wales, that if similarity of fossil forms are to govern us in determining the relation of formations, then those stratified rocks exhibited on the shore at Big-Free-Port and to Balleochreoch, folding over and surrounding the basic conglomerate mass, can only be placed in a similar stratigraphical position to those referred to by the above able authors, thus extending our knowledge of Cambrian rocks occurring further south in Scotland than has been hitherto recorded. The author quite agreed with Prof. Ramsay in supposing that these rocks were deposited in an inland and freshwater lake; and that those cracks are due to the influence of the sun is abundantly evident. If they had been deposited in an estuary of the sea, the soft mud would not have got time to crack, as each inflowing tide would have kept the matrix sufficiently moist to prevent its shrinking.

3rd. The metamorphic rocks on the western extremity of the island, and skirting the shores of Lochendale for nine miles to the east, and dipping S.S.W. or nearly at right angles to the plains of stratification of the preceding deposits, are of Laurentian age. They differ so widely both in mineral character and stratigraphical aspect from those of the central valley and eastern side of the island, that there can be little doubt regarding their proper identification. Their lithological aspect and mineral character coincides so well with the fundamental Gneiss of Sutherlandshire, and designated by Sir Roderick Murchison as of Laurentian age, that we have not the slightest hesitation in identifying those of Islay as belonging to the same period.

4th. In the basic conglomerates on the eastern side of the island we have got traces of striated rocks imbedded in the mass, although we are not prepared to speak with any degree of certainty regarding the source or direction of the materials constituting the conglomerate mass. If, however, we glance at the topographical aspect of the Highlands and Island, and compare the imbedded boulders of granite with the granites found *in situ* throughout the Highlands, we feel the necessity of tracing them to another source, and hope we do not overstep the bounds of prudent speculation in suggesting that those erratics are the reassorted materials of some great northern continent that has yielded to the ceaseless gnawing tooth of time, leaving those scattered fragments as the wreckage of its former greatness, and that the materials of which the mass is composed have in time, deeper than we have hitherto suspected, been transported by the agency of ice. If so, then this is another proof that we are not in a position to limit the agency of ice to any single period of our earth's history.

Additions to the Fossil Vertebrate Fauna of Burdiehouse, near Edinburgh. By Prof. TRAQUAIR.

On the Structure of the Dictyoxylons *of the Coal-measures. By* Professor W. C. WILLIAMSON, *F.R.S.*

Professor W. C. Williamson referred to Mr. Binney's original description, in 1866, of *Dadoxylon Oldhamium,* and to his own subsequent paper, in which he separated his new genus *Dictyoxylon* from the *Dadoxylons.* He then described the former genus in detail, commencing with *D. Oldhamium.* In this plant there was

a central medullary axis of cellular tissue with several detached longitudinal bundles of vascular tissue at its circumference. Outside this is a lax ligneous zone, to the interior of which the bundles just referred to are adherent. The vessels of the ligneous zone are reticulated, and arranged in radiating series, the radiating laminæ being separated at very frequent intervals by thick cellular medullary rays, consisting of numerous vertical series of cells. External to the woody zone is a very thick and characteristic bark, the inner portion of which is loosely cellular, but the exterior has a different structure. It consists of a combination of cellular parenchyma and dense elongated prosenchyma, the latter appearing in the transverse section as a series of dark bands, radiating at varying angles from the inner to the epidermal layer of the outer bark. Vertically these prosenchymatous bands are prolonged as layers, which extend upwards and downwards in a wavy manner, alternately approaching and receding from one another, so that a tangential section exhibits a series of lenticular areolæ whose longer axes correspond with that of the stem. The outermost bark-layer appears to be a cellular epidermal tissue, which has probably supported external appendages, either scales or leaves. In the inner layer of the bark we see a series of variously developed vascular bundles which spring as branches from the ligneous zone, but which ascend for a considerable distance without escaping through the bark, whilst a second series of branches are given off in like manner, but which at once perforate the bark in their passage outwards. This plant is from the lower coal-measures of Lancashire and Yorkshire.

A second form of *Dictyoxylon*, to which the author gives the name of *D. radicans*, has evidently been a branching root which has been traced continuously into its ultimate rootlets. This plant has no pith, and its compact woody zone, consisting of reticulated vessels, is furnished with medullary rays of a much simpler construction than those of *D. Oldhamium*. They are not unfrequently represented in the tangential section by a single cell; and there are rarely more than five or six such cells in each vertical pile. The bark consists of parenchymatous cells arranged in rows perpendicular to the surface. This is also a Lancashire form.

A third species of *Dictyoxylon* discovered in beds of the lower Carboniferous series of Burntisland is named *D. Grievii* after its discoverer, Mr. Grieve. Its central axis is much deranged, resembling the *Heterangium paradoxum* of Corda; but several specimens have occurred showing that there was a central vascular axis surrounded by a lax radiating ligneous zone, which in turn was invested by a remarkable cellular bark, which exhibited, both in radiating and tangential sections, a characteristic series of parallel horizontal lines, resulting from a peculiar condition of the cellular parenchyma at the points where they exist. As in *D. Oldhamium*, vascular bundles ascend through the inner bark. The plants described were connected by the author with some large casts of bark from the Coal-measures, some of which have been described as Sagenariæ and Lyginodendra. These specimens have upon their surface elongated lenticular scars arranged as in *Lepidodendron*; but usually much more elongated in a vertical direction than in that genus, and always lacking the central spots marking the issue of vascular bundles. These areolæ are not leaf-scars, but casts of depressions in the outer surface of the bark from which the epidermis was removed, and which correspond with the spaces enclosed by the sinuosities of the prosenchymatous layers. The functional uses of these areolæ are undetermined, and there is as yet much uncertainty as to the true affinities of the genus.

On the Structure of Diploxylon, *a Plant of the Carboniferous Rocks. By* Professor W. C. Williamson, *F.R.S.*

On the Discovery of a new and very perfect Arachnide from the Ironstone of the Dudley Coal-field. By Henry Woodward, *F.G.S., F.Z.S., &c., of the British Museum.*

The Penny-stone Ironstone of the Coalbrook Dale Coal-field has long been celebrated for yielding, when the nodules are split, impressions of leaves of ferns, *Lepidostrobi* and other fruits, King-crabs, and the rare remains of Insects.

A recently discovered and very perfect specimen of the so-called *Curculioides Prestvicii* of Buckland (figured in his 'Bridgewater Treatise,' pl. 46″, fig. 2), from Dudley, proves this insect to have been one of the "False Scorpions," nearly related to the living genus *Phrynus*, and not a Coleopterous insect as supposed by Samouelle.

The specimen is so preserved as to expose its dorsal and ventral aspect each distinctly preserved upon the two halves of the nodule; the former richly ornamented with rows and rosettes of tubercles, and the latter showing the smooth segmented under-surface of the body bearing the tracheal openings. The hinder border bears four short and stout spines. Four pairs of legs are seen, whose wedge-shaped basal joints meet beneath the cephalothorax, which is very tumid, and has a rather prominent rostrum, probably giving rise to Mr. Samouelle's mistake of calling it a *Curculio*. Mr. Woodward proposed to name this new genus of "false scorpions" *Eophrynus*, retaining the name *Curculioides* for *C. Ansticii*, another example which may truly belong to the *Rhynchophora*. There are now 44 insects known and described from the Coal-measures, namely 8 Arachnida, 5 Myriapoda, 3 Coleoptera, 13 Orthoptera, 14 Neuroptera, and a doubtful Lepidopterous insect.

Relics of the Carboniferous and other old Land-surfaces. *By* Henry Woodward, *F.G.S.*, *F.Z.S.*

Whilst admitting that during particular eras circumstances may have favoured the development of special groups of organisms, which in consequence flourished in greater abundance than the rest, the author deprecated the idea of the prevalence of peculiar conditions at any time since the advent of organic life on the globe.

Although in the earlier Palæozoic rocks we have little or no evidences of land, yet the fact of stratified deposits being formed at the bottom of the sea is positive evidence of the waste of neighbouring land-surfaces, which must have been always in existence. And further, if conditions in the sea were favourable to the development of abundance of animal life, those on the land were in all probability equally so.

Mr. Woodward referred to the abundance of evidence of land-surfaces everywhere, both in Quaternary and in Tertiary times, the former differing but little, save in the geographical distribution of its fauna, from that of the present day, the latter differing more and more from the existing fauna and flora, and also in its relation to existing lands. When, however, the base of the Tertiaries is reached, the land-surfaces are divided by greater marine accumulations; nevertheless we find, both in Europe and America, freshwater deposits with remains of land-plants and animals often in rich abundance. Even the truly marine deposits (such as the Chalk) testify to the presence of land by the fossil remains of Pterodactyles, Cheloniæ, and other shore-dwelling reptiles.

Mr. Woodward instanced the Wealden beds, the Purbeck limestone, and Oolitic plant-shales as affording abundant proofs of Mesozoic lands, whilst truly marine accumulations (such as the Solenhofen limestone) contain swarms of insects, flying lizards, and a true bird, with branches of Coniferæ and other trees to tell of a land-fauna adjacent to its waters.

The author noticed the earliest mammals found in the Triassic bone-beds of Stuttgart and Somerset, and the ripple-marked slabs covered with bird-like tracks and Labyrinthodont foot-marks, telling of the denizens of the old Triassic sea-shores and lakes.

He next described the coal-period, with its stores of land-plants and Reptilia, both aquatic and terrestrial, its insects and mollusca. He controverted the arguments of Dr. T. Sterry Hunt as to the exceptional condition of the atmosphere of the Coal-period, and showed that the presence of animal life disproved the existence of an atmosphere charged with carbonic acid gas, and that plants would not be benefitted thereby, as Dr. Hunt supposed.

With respect to the wide distribution of coal, Mr. Woodward pointed out that it was not necessary to assume that all coal was formed throughout the world during one and the same epoch, but, on the contrary, he showed that coal might be alike as regards its fauna and flora, and yet of very widely different ages.

He advocated the formation of coal from the slow but sure accumulation of peat-growth, as that mode of conservation of vegetable matter was proved to be the most certain to yield pure hydrocarbons such as we find the coal to consist of, *unmixed with foreign matter.* Such pure accumulations could not (in the opinion of the author) be formed in river-valleys, deltas of great rivers, or in marine swamps and marshes, but on wide plains covered with a thick vegetation, and tending, by its clayey soil, to check drainage and produce peat-growth.

Mr. Woodward referred to the discoveries of Devonian land-plants and insects by Dr. Dawson in North America, and to the occurrence of seed-spores of land-plants in Silurian strata; he suggested that the veins of Graphite may be accepted as evidence of old coal-seams, altered by heat and pressure; and that the oil-springs in the Silurian rocks may be due to the destructive distillation of old coal-beds in Nature's own retort.

BIOLOGY.

Address by Dr. ALLEN THOMSON, *F.R.SS. L. & E., Professor of Anatomy in the University of Glasgow, President of the Section.*

IN now opening the Meetings of the Biological Section, it is my first duty to express my deep sense of the honour which has been conferred upon me in appointing me to preside over its deliberations. I trust that my grateful acceptance of the office will not appear to be an assumption on my part of more than a partial connexion with the very wide field of science included under the term Biology. I should gladly have embraced the opportunity now afforded me of conforming to a custom which has of late become almost the rule with the Presidents of Sections, viz. that of bringing under your review a notice of the more valuable discoveries with which our science has been enriched in recent times, were it not that the subjects which I might have been disposed to select would require an amount of detail in each which would necessarily limit greatly their number, and that any attempt to overtake the whole range of this widespread department of science, even in the most general remarks, would be equally presumptuous and futile on the part of one whose attention has been restricted mainly to one of its divisions. I am further embarrassed in the choice of topics for general remark by the circumstance that many of those upon which I might have ventured to address you have been most ably treated of by my predecessors, as, for example, in the Sectional Addresses of Dr. Acland, Dr. Sharpey, Mr. Berkeley, Dr. Humphry, and Dr. Rolleston, as well as in the General Presidential Addresses of Dr. Hooker and Professor Huxley. I must content myself, therefore, with endeavouring to convey to you some of the ideas which arise in my mind in looking back from the present upon the state of Biological Science at the time when, forty years since, the Meetings of the British Association commenced—a period which I am tempted to particularize from its happening to coincide very nearly with that at which I began my career as a public teacher in one of the departments of Biology in this city. In the few remarks which I shall make, it will be my object to show the prodigious advance which has taken place not only in the knowledge of our subject as a whole, but also in the ascertained relation of its parts to each other, and in the place which Biological knowledge has gained in the estimation of the educated part of the community, and the consequent increase in the freedom with which the search after truth is now asserted in this as in other departments of science.

And first, in connexion with the distribution of the various subjects which are included under this Section, I may remark that the general title under which the whole Section D has met since 1866, viz. Biology, seems to be advantageous both from its convenience, and as tending to promote the greater consolidation of our science, and a juster appreciation of the relation of its several parts. It may be that, looking merely to the derivation of the term, it is strictly more nearly synony-

mous with physiology in the sense in which that word has been for a long time employed, and therefore designating the science of life, rather than the description of the living beings in which it is manifested. But until a better or more comprehensive term be found, we may accept that of biology under the general definition of "the science of life and of living beings," or as comprehending the history of the whole range of organic nature—vegetable as well as animal. The propriety of the adoption of such a general term is further shown by a glance at the changes which the titles and distribution of the subordinate departments of this Section have undergone during the period of the existence of the Association.

During the first four years of this period the Section met under the combined designation of Zoology and Botany, Physiology and Anatomy—words sufficiently clearly indicating the scope of its subjects of investigation. In the next ten years a connexion with Medicine was recognized by the establishment of a subsection or department of Medical Science, in which, however, scientific anatomy and physiology formed the most prominent topics, though not to the exclusion of more strictly medical and surgical or professional subjects. During the next decade, or from the year 1845 to 1854, we find along with Zoology and Botany a subsection of Physiology, and in several years of the same time along with the latter a separate department of Ethnology. In the eleven years which extended from 1855 to 1865, the branch of Ethnology was associated with Geography in Section E. More recently, or since the arrangement which was commenced in 1866, the Section Biology has included, with some slight variation, the whole of its subjects in three departments. Under one of these are brought all investigations in Anatomy and Physiology of a general kind, thus embracing the whole range of these sciences when without special application. A second of these departments has been occupied with the extensive subjects of Botany and Zoology; while the third has been devoted to the subject of Anthropology, in which all researches having a special reference to the structure and functions or life-history of man have been received and discussed. Such I understand to be the arrangement under which we shall meet on this occasion. At the conclusion of my remarks, therefore, the department of Anatomy and Physiology will remain with me in this room; while that of Zoology and Botany, on the one hand, and of Anthropology on the other, will adjourn to the apartments which have been provided for them respectively.

With regard to the position of Anthropology, as including Ethnology, and comprehending the whole natural history of man, there may be still some differences of opinion, according to the point of view from which its phenomena are regarded: as by some they may be viewed chiefly in relation to the bodily structure and functions of individuals or numbers of men; or as by others they may be considered more directly with reference to their national character and history, and the affinities of languages and customs; or by a third set of inquirers, as bearing more immediately upon the origin of man and his relation to animals. As the first and third of these sets of topics entirely belong to Biology, and as those parts of the second set which do not properly fall under that branch may with propriety find a place under Geography or Statistics, I feel inclined to adhere to the distinct recognition of a department of Anthropology, in its present form; and I think that the suitableness of this arrangement is apparent, from the nature and number of the appropriate reports and communications which have been received under the last distribution of the subjects.

The beneficial influence of the British Association in promoting biological research is shown by the fact that the number of the communications to the Sections, received annually has been nearly doubled in the course of the last twenty years. And this influence has doubtless been materially assisted by the contributions in money made by the Association in aid of various biological investigations; for it appears that, out of the whole sum of nearly £34,500 contributed by the Association to the promotion of scientific research, about £2800 has been devoted to biological purposes, to which it would be fair to add a part at least of the grants for Palæontological researches, many of which must be acknowledged to stand in close relation to Biology.

The enormous extent of knowledge and research in the various departments of Biology has become a serious impediment to its more complete study, and leads to

the danger of confined views on the part of those whose attention, from necessity or taste, is too exclusively directed to the details of one department, or even, as often happens, to a subdivision of it. It would seem, indeed, as if our predecessors in the last generation possessed this superior advantage in the then existing narrower boundaries of knowledge, that it was possible for them to overtake the contemplation of a wider field, and to follow out researches in a greater number of the sciences. To such combination of varied knowledge, united with their transcendent powers of sound generalization and accurate observation, must be ascribed the widespread and enduring influence of the works of such men as Haller, Linnæus, Cuvier, Von Baer, and Johannes Müller. There are doubtless brilliant instances in our own time of men endowed with similar powers; but the difficulty of bringing these powers into effectual operation in a wide range is now so great, that, while the amount of research in special biological subjects is enormous, it must be reserved for comparatively few to be the authors of great systems, or of enduring broad and general views which embrace the whole range of biological science. It is incumbent, therefore, on all those who are desirous of promoting the advance of biological knowledge to combat the confined views which are apt to be engendered by the too great restriction of study to one department. However much subdivision of labour may now be necessary in the original investigation and elaboration of new facts in our science (and the necessity for such subdivision will necessarily increase as knowledge extends), there must be secured at first, by a wider study of the general principles and some of the details of collateral branches of knowledge, that power of justly comparing and correlating facts which will mature the judgment and exclude partial views. To refer only to one bright example, I might say that it can scarcely be doubted that it is the unequalled variety and extent of knowledge, combined with the faculty of bringing the most varied facts together in new combination, which has enabled Dr. Darwin (whatever may be thought otherwise of his system) to give the greatest impulse which has been felt in our own times to the progress of biological views and thought; and it is most satisfactory to observe the effect which this influence is already producing on the scientific mind of this country, in opposing the tendency perceptible in recent times to the too restricted study of special departments of natural history. I need scarcely remind you that for the proper investigation and judgment of problems in physiology, a full knowledge of anatomy in general, and much of comparative anatomy, of histology and embryology, of organic chemistry and of physics, is indispensable as a preliminary to all successful physiological observation and experiment. The anatomist, again, who would profess to describe rationally and correctly the structure of the human body, must have acquired a knowledge of the principles of morphology derived from the study of comparative anatomy and development, and he must have mastered the intricacies of histological research. The comparative anatomist must be an accomplished embryologist in the whole range of the animal kingdom, or in any single division of it which he professes to cultivate. The zoologist and the botanist must equally found their descriptions and systematic distinctions on morphological, histological, and embryological data. And thus the whole of these departments of biological science are so interwoven and united that the scientific investigation of no one can now be regarded as altogether separate from that of the others. It has been the work of the last forty years to bring that intimate connexion of the biological sciences more and more fully into prominent view, and to infuse its spirit into all scientific investigation. But while in all the departments of biology prodigious advances have been made, there are two more especially which merit particular mention as having almost taken their origin within the period I now refer to, as having made the most rapid progress in themselves, and as having influenced most powerfully and widely the progress of discovery, and the views of biologists in other departments—I mean Histology and Embryology.

I need scarcely remind those present that it was only within a few years before the foundation of the British Association that the suggestions of Lister in regard to the construction of achromatic lenses brought the compound microscope into such a state of improvement as caused it to be restored, as I might say, to the place which the more imperfect instrument had lost in the previous century. The re-

sult of this restoration became apparent in the foundation of a new era in the knowledge of the minute characters of textural structure, under the joint guidance of Robert Brown and Ehrenberg, with contributions from many other observers, so as at last to have almost entitled this branch of inquiry to its designation, by Mr. Huxley, of the exhaustive investigation of structural elements. All who hear me are aware of the influence which, from 1839 onwards, the researches of Schwann and Schleiden exerted on the progress of Histology and the views of anatomists and physiologists as to the structure and development of the textures both of plants and animals, and the prodigious increase which followed in varied microscopic observations. It is not for me here even to allude to the steps of that rapid progress by which a new branch of anatomical science has been created; nor can I venture to enter upon any of the interesting questions presented by this department of microscopic anatomy; nor attempt to discuss any of those difficult problems possessing so much interest at the present moment, such as the nature of the organized cell or the properties of protoplasm. I would only remark that it is now very generally admitted that the cell-wall (as Schwann indeed himself pointed out) is not a constant constituent of the cell, nor a source of new production, though still capable of considerable structural change after the time of its first formation. The nucleus has also lost some of the importance attached to it by Schwann and his earlier followers, as an essential constituent of the cell, while the protoplasm of the cell remains in undisputed possession of the field as the more immediate seat of the phenomena of growth and organization, and of the contractile property which forms so remarkable a feature of their substance. I cordially agree with much of what Mr. Huxley has written on this subject in 1853 and 1869. The term physical basis of life may perhaps be in some respect objectionable; but I look upon the recognition of protoplasm which he has enforced as a most important step in the recent progress of histology, adopting this general term to indicate that part of the organized substance of plants and animals which is the constant seat of the growing and moving powers, but not implying identity of nature and properties in all the variety of circumstances in which it may occur. To Haeckel the fuller history of protoplasm in its lowest forms is due. To Dr. Beale we owe the minutest and most recent investigation of these properties by the use of magnifying-powers beyond any that had previously been known, and the successful employment of reagents which appear to mark out its distinction * from the other elements of the textures. I may remark, however, in passing, that I am inclined to regard contractile protoplasm, whether vegetable or animal, as in no instance entirely amorphous or homogeneous, but rather as always presenting some minute molecular structure which distinguishes it from parts of glassy clearness. Admitting that the form it assumes is not necessarily that of a regular cell, and may be various and irregular in a few exceptional instances, I am not on that account disposed to give up definite structure as one of the universal characteristics of organization in living bodies. I would also suggest that the terms formative and non-formative, or some other such, would be preferable to those of "living and dead," employed by Dr. Beale to distinguish the protoplasm from the cell-wall or its derivatives, as these latter terms are liable to introduce confusion.

To the discoveries in embryology and development I might have been tempted to refer more at large, as being those which have had, of all modern research, the greatest effect in extending and modifying biological views, but I am warned from entering upon a subject in which I might trespass too much on your patience. The merits of Wolff as the great leader in the accurate observation of the phenomena of development were clearly pointed out by Mr. Huxley in his presidential address of last year. Under the influence of Döllinger's teaching, Pander, and afterwards Purkinje, Von Baer, and Rathke, established the foundations of the modern history of embryology. It was only in the year 1827 that the ovum of mammals was discovered by Von Baer; the segmentation of the yelk, first observed by Prevost and Dumas in the frog's ovum in 1824, was ascertained to be general in succeeding years; so that the whole of the interesting and important additions which have followed, and have made the history of embryological development a complete science, have been included within the eventful

* Under the appropriate name of "bioplasm."

period of the life of this Association. I need not say how distinguished the Germans have been by their contributions to the history of animal development. The names of Valentin, R. Wagner, Bischoff, Reichert, Kölliker, and Remak are sufficient to indicate the most important of the earlier steps in recent progress, without attempting to enumerate a host of others who have assisted in the great work thus founded.

I am aware that the mere name of development suggests to some ideas of a disturbing kind as being associated with the theory of evolution recently promulgated. To one accustomed during the whole of his career to trace the steps by which every living being, including man himself, passes from the condition of an almost imperceptible germ, through a long series of changes of form and structure into their perfect state, the name of development is suggestive rather of that which seems to be the common history of all living beings; and it is not wonderful therefore that such a one should regard with approval the more extended view which supposes a process of development to belong to the whole of nature. How far that principle may be carried, to what point the origin of man or any animal can by facts or reasoning be traced in the long unchronicled history of the world, and whether living beings may arise independently of parents or germs of previously existing organisms, or may spring from the direct combination of the elements of dead matter, are questions still to be solved, and upon which we may expect this Section to guide the hesitating opinion of the time. I cannot better express the state of opinion in which I find myself in regard to the last of these problems, than by quoting the words of Professor Huxley from his address of last year, p. lxxxiii :—

"But though I cannot express this conviction of mine too strongly [viz. that the evidence of the most careful experiments is opposed to the occurrence of spontaneous generation], I must carefully guard myself against the supposition that I intend to suggest that no such thing as abiogenesis ever has taken place in the past, or ever will take place in the future. With organic chemistry, molecular physics, and physiology yet in their infancy, and every day making prodigious strides, I think it would be the height of presumption for any man to say that the conditions under which matter assumes the properties we call 'vital,' may not, some day, be artificially brought together." And again, "If it were given me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions, which it can no more see again than a man can recall his infancy, I should expect to be a witness of the evolution of living protoplasm from not living matter." I will quote further a few wise words from the discourse to which many of you must have listened last evening with admiration. Sir William Thomson said :— "The essence of science, as is well illustrated by astronomy and cosmical physics, consists in inferring antecedent conditions, and anticipating future evolutions, from phenomena which have actually come under observation. In biology, the difficulties of successfully acting up to this ideal are prodigious. Our code of biological law is an expression of our ignorance as well as of our knowledge." And again, "Search for spontaneous generation out of inorganic materials; let any one not satisfied with the purely negative testimony of which we have now so much against it, throw himself into the inquiry. Such investigations as those of Pasteur, Pouchet, and Bastian are among the most interesting and momentous in the whole range of natural history, and their results, whether positive or negative, must richly reward the most careful and laborious experimenting."

The consideration of the finest discoverable structures of the organized parts of living bodies is intimately bound up with that of their chemical composition and properties. The progress which has been made in organic chemistry belongs not only to the knowledge of the composition of the constituents of organized bodies, but also to the manner in which that composition is chemically viewed. Its peculiar feature, especially as related to biological investigation, consists in the results of the introduction of the synthetic method of research, which has enabled the chemist to imitate or to form artificially a greater and greater number of the organic compounds. In 1828 the first of these substances was formed by Wöhler, by a synthetic process, as cyanate of ammonia. But still, at that time, though a few no doubt entertained juster views,

the opinion generally prevailed among chemists and physiologists that there was some great and fundamental difference in the chemical phenomena and laws of organic and inorganic nature. Now, however, this supposed barrier has been in a great measure broken down and removed, and chemists, with almost one accord, regard the laws of combination of the elements as essentially the same in both classes of bodies, whatever differences may exist in actual composition, or in the reactions of organic bodies in the more complex and often obscure conditions of vitality, as compared with the simpler and, on the whole, better known phenomena of a chemical nature observed in the mineral kingdom. Thus, by the synthetic method, there have been formed among the simpler organic compounds a great number of alcohols, hydrocarbons, and fatty acids. But the most remarkable example of the synthetic formation of an organic compound is that of the alkaloid conia, as recently obtained by Hugo Schiff by certain reactions from butyric aldehyde, itself an artificial product. The substance so formed, and its compounds, possess all the properties of the natural conia—chemical, physical, and physiological—being equally poisonous with it. The colouring-matter of madder, or alizarine, is another organic compound which has been formed by artificial processes. It is true that the organized or containing solid, either of vegetable or animal bodies, has not as yet yielded to the ingenuity of chemical artifice; nor, indeed, is the actual composition of one of the most important of these, albumen and its allies, fully known. But as chemists have only recently begun to discover the track by which they may be led to the synthesis of organic compounds, it is warrantable to hope that ere long cellulose and lignine may be formed; and, great as the difficulties with regard to the albumenoid compounds may at present appear, the synthetic formation of these is by no means to be despaired of, but, on the contrary, may with confidence be expected to crown their efforts. From all recent research, therefore, it appears to result that the general nature of the properties belonging to the products of animal and vegetable life can no longer be regarded as different from those of minerals, in so far at least as they are the subject of chemical and physical investigation. The union of elements and their separation, whether occurring in an animal, a vegetable, or a mineral body, must be looked upon as dependent on innate powers or properties belonging to the elements themselves; and the phenomena of change of composition of organic bodies occurring in the living state are not the less chemical because they are different from those observed in inorganic nature. All chemical actions are liable to vary according to the conditions in which they occur; and many instances might be adduced of most remarkable variations of this kind, observed in the chemistry of dead bodies from very slight changes of electrical, calorific, mechanical, and other conditions. But because the conditions of action or change are infinitely more complex and far less known in living bodies, it is not necessary to look upon the phenomena as essentially of a different kind, to have recourse to the hypothesis of vital affinities, and still less to shelter ourselves under the slim curtain of ignorance implied in the explanation of the most varied chemical changes by the influence of a vital principle.

On the subjects of zoological and botanical classification and anthropology, it would be out of place for me now to make any observations at length. I will only remark, in regard to the first, that the period now under review has witnessed a very great modification in the aspect in which the affinities of the bodies belonging to these two great kingdoms of nature are viewed by naturalists, and the principles on which groups of bodies in each are associated together in systematic classification; for, in the first place, the older view has been abandoned that the complication of structure rises in a continually increasing and continuous gradation from one kingdom to the other, or extends in one line, as it were, from group to group in either of the kingdoms separately. Evolution into a gradually increasing complexity of structure and function no doubt exists in both, so that types or general plans of formation must be acknowledged to exist, presenting typical resemblances of the deepest interest; but in the progress of morphological research it has become more and more apparent that the different groups form radiations, which touch one another at certain points of greatest resemblance, rather than one continuous line, or a number of lines which partially pass each other. The

simpler bodies of the two kingdoms of nature exhibit a gradually increasing resemblance to each other, until at last the differences between them wholly disappear, and we reach a point of contact at which the properties become almost indistinguishable, as in the remarkable Protista of Haeckel and others. I fully agree, however, with the view stated by Professor Wyville Thomson in his recent introductory lecture, that it is not necessary on this account to recognize, with Haeckel, a third or intermediate kingdom of nature. Each kingdom presents, as it were, a radiating expansion into groups for itself, so that the relations of the two kingdoms might be represented by the divergence of lines spreading in two different directions from a common point. Recent observations on the chorda dorsalis, or supposed notochord, of some Ascidians, tend to revive the discussion, at one time prevalent, but long in abeyance, as to the possibility of tracing an homology between the vertebrate and invertebrate animals; and, should this correspondence be confirmed and extended, it may be expected to modify greatly our present views of zoological affinities and classification. It will also be an additional proof of the importance of minute and embryological research in systematic determinations. The recognition of homological resemblance of animals, to which in this country the researches of Owen and Huxley have contributed so largely, form one of the most interesting subjects of contemplation in the study of comparative anatomy and zoology in our time; but I must refrain from touching on so seductive and difficult a subject.

There is another topic to which I can refer with pleasure as connected with the cultivation of biological knowledge in this country, and that is the introduction of instruction in natural science into the system of education of our schools. As to the feasibility of this in the primary schools, I believe most of those who are intimately acquainted with their management have expressed a decidedly favourable opinion—it being found that a portion of the time now allotted to the three great requisites of a primary education might with advantage be set apart, for the purpose of instructing the pupils in subjects of common interest, calculated to awaken in their minds a desire for knowledge of the various objects presented by the field of nature around them. As to the benefit which may result from this measure to the persons so instructed, it is scarcely necessary for me to say anything in this place. It is so obvious that any varied knowledge, however easily acquired or elementary, which tends to enlarge the range of observation and thought, must have some effect in removing its recipients from grosser influences, and may even supply information which may prove useful in social economy and in the occupations of labour. Nor need I point out how much more extended the advantages of such instruction may prove if introduced into the system of our secondary schools, and more freely combined than heretofore with the too exclusively literary and philosophical study which has so long prevailed in the approved British education. Without disparagement to those modes of study as in themselves necessary and useful, and excellent means of disciplining the mind to learning, I cannot but hold it as certain that the mind which is entirely without scientific cultivation is but half prepared for the common purposes of modern life, and is entirely unqualified for forming a judgment on some of the most difficult and yet most common and important questions of the day, affecting the interests of the whole community. I refer with pleasure to the published Essay of Dr. Lankester on this subject, and to the arguments addressed two days ago by Dr. Bennett to the medical graduates of the University, in favour of the establishment of physiology as a subject of general education in this country with reference to sanitary conditions. It is gratifying, therefore, to perceive that the suggestions made some years ago in regard to this subject by the British Association, through its committee, have already borne good fruit, and that the attention of those who preside over education in this country, as well as of the public themselves, is more earnestly directed to the object of securing for the lowest as well as the highest classes of the community that wholesome combination of knowledge derived from education, which will duly cultivate all the faculties of the mind, and thus fit a greater and greater number for applying themselves with increased ability and knowledge to the purposes of their living and its improved condition. If the law of the survival of the fittest be applicable to the mental as well as to the physical improvement

of our race (and who can doubt that in some measure it must be so?), we are bound by motives of interest and duty to secure for all classes of the people that kind of education which will lead to the development of the highest and most varied mental power. And no one who has been observant of the recent progress of the useful arts and its influence upon the moral, social, and political condition of our population, can doubt that such education must include instruction in the phenomena of external nature, including, more especially, the laws and conditions of life and health; and that it ought to be, at the same time, such as will adapt the mind to the ready acquisition and just comprehension of varied knowledge. It is obvious, too, that while this more immediately useful or beneficial effect on the common mind may be produced by the diffusion of natural knowledge among the people, biological science will share in the gain accruing to all branches of natural science, by the greater favour which will be accorded to its cultivators, and the increased freedom from prejudice with which their statements are received and considered by learned as well as by unscientific persons.

I cannot conclude these observations without adverting to one aspect in which it may be thought that the appreciation of biological science has taken a retrograde rather than an advanced position. In this, I do not mean to refer to the special cultivators of biology in its scientific acceptation, but to the fact that there appears to have taken place of late a considerable increase in the number of persons who believe, or who imagine that they believe, in the class of phenomena which are now called spiritual, but which have been known, since the exhibitions of Mesmer, and, indeed, long before his time, under the most varied forms, as liable to occur in persons of an imaginative turn of mind and peculiar nervous susceptibility. It is to be regretted that a number of persons devote a large share of their time to the practice (for it does not deserve the name of study or investigation) of the alleged phenomena, and that a few men of acknowledged reputation in some departments of science have lent their names, and surrendered their judgment, to the countenance and attempted authentication of the delusive dreams of the practitioners of spiritualism, and similar chimerical hypotheses. The natural tendency to a belief in the marvellous is sufficient to explain the ready acceptance of such views by the ignorant; and it is not improbable that a higher species of similar credulity may frequently act with persons of greater cultivation, should their scientific information and training have been of a partial kind. It must be admitted, further, that extremely curious and rare and, to those who are not acquainted with the nervous functions, apparently marvellous phenomena, present themselves in peculiar states of the nervous system—some of which states may be induced through the mind and may be made more and more liable to recur, and to be greatly exaggerated by frequent repetition. But making the fullest allowance for all these conditions, it is still surprising that persons, otherwise appearing not to be irrational, should entertain a confirmed belief in the possibility of phenomena, which, while they are at variance with the best established physical laws, have never been brought under proof by the evidences of the senses, and are opposed to the dictates of sound judgment. It is so far satisfactory, in the interests of true biological science, that no man of note can be named from the long list of thoroughly well-informed anatomists and physiologists, who has not treated the belief in the separate existence of powers of animal magnetism and spiritualism as wild speculations, devoid of all foundation in the carefully tested observation of facts. It has been the habit of the votaries of the systems to which I have referred to assert that scientific men have neglected or declined to investigate the phenomena with attention and candour; but nothing can be further from the truth than this statement. Not to mention the admirable reports of the early French academicians, giving the account of the negative result of an examination of the earlier mesmeric phenomena by men in every way qualified to pronounce judgment on their nature, I am aware that from time to time men of eminence, and fully competent, by their knowledge of biological phenomena, and their skill and accuracy in conducting scientific investigation, have made the most patient and careful examination of the evidence placed before them by the professed believers and practitioners of so-called mesmeric, magnetic, phrenomagnetic, electrobiological, and other like phenomena; and the result has been uniformly the same in all cases when they

were permitted to secure conditions by which the reality of the phenomena, or the justice of their interpretation, could be tested, viz. either that, on the one hand, the phenomena were not essentially different from those well known to physiologists as modifications of the nervous and muscular functions under peculiar mental states; or that, on the other hand, the experiments signally failed to educe the results professed, or that the experimenters were detected in shameless and determined impostures. I have myself been fully convinced of this by repeated examinations; and I can scarcely doubt that the same fate awaits the fair scientific examination of the so-called spiritualistic phenomena*. But were any guarantee required for the care, soundness, and efficiency of the judgment of men of science on such phenomena and views, I have only to mention, in the first place, the revered name of Faraday, and in the next that of my life-long friend Dr. Sharpey, whose ability and candour none will dispute, and who, I am happy to think, is here among us, ready, from his past experience of such exhibitions, to bear his testimony against all cases of *levitation*, or the like, which may be the last wonder of the day among the mesmeric or spiritual pseudo-physiologists. The phenomena to which I have at present referred are in great part dependent upon natural principles of the human mind, placed, as it would appear, in dangerous alliance with certain tendencies of the nervous system. They ought not to be worked upon without the greatest caution, and they can only be fully understood by the accomplished physiologist who is also conversant with healthy and morbid psychology. The experience of the last hundred years tends to show that, while there are always to be found persons peculiarly liable to exhibit the phenomena in question, there will also exist a certain number of minds prone to adopt a belief in the marvellous and striking in preference to that which is easily understood and patent to the senses; but it may be confidently expected that the diffusion of a fuller and more accurate knowledge of physiology among the non-scientific classes of the community may lead to a juster appreciation of the phenomena in question, and a reduction of the number among them who are believers in scientific impossibilities.

On some new Experiments relating to the Origin of Life. By Dr. CHARLTON BASTIAN, *F.R.S.*

On the Action of Heat on Germ-life. By F. CRACE-CALVERT, *F.R.S.*

The question of building ovens for disinfecting purposes, gives the subject of this paper more than a merely scientific interest, as it thus becomes one of great practical importance. As it is found that certain forms of life can exist when exposed to a temperature equal to that at which the charring of organic matter commences, it is unsafe to assume that the particular forms of life which propagate certain forms of disease will be destroyed below this temperature. As from the nature of the case stoving can only be partially applicable, and as it is at present not proved effective where it is applicable, it is unadvisable to spend public money until a greater degree of certainty is arrived at.

The experiments described were not, however, undertaken with an intention of influencing the settlement of this question, but were part of a series on the question of putrefaction and the development of life.

It has hitherto been assumed by the advocates of the theory of spontaneous generation, that a temperature of 212° Fahr., or the boiling-point of the fluid operated on, was sufficient to destroy all protoplasmic life, and that any life subsequently observed in such fluids must have been developed from non-living matter.

* In consequence of several remonstrances made to me since the address was delivered, representing that the phenomena of spiritualism had not yet been subjected to a full scientific investigation, I have been induced to alter the two preceding sentences from their original into their present form. But I am still of opinion that these phenomena belong essentially to the same class as those of Mesmerism and Electrobiology.

To determine this point experiments were made with solution of sugar, hay infusion, solution of gelatine, and water that had been in contact with putrid meat.

To carry out these experiments, the author prepared a series of small tubes made of very thick well-annealed glass, each tube about 4 centimetres in length and having a bore of 5 millimetres. The fluid to be operated upon was introduced into them, and left exposed to the atmosphere for a sufficient length of time for germ-life to be largely developed. Each tube was then hermetically sealed and wrapped in wire gauze. They were then placed in an oil-bath and gradually heated to the required temperature, at which they were maintained for half an hour.

The sugar solution was prepared by dissolving one part of sugar in ten parts of common water, and exposed to the atmosphere all night, so that life might impregnate it, then placed in tubes and allowed to stand five days. Some of the tubes were kept without being heated, others heated to 200, 300, 400, and 500° Fahr. respectively. After being kept twenty-four days, the contents of the tubes were microscopically examined.

In the solution not heated, much life was seen; at 212° a great portion of the life had disappeared, at 300° the sugar was slightly charred but the life not entirely destroyed, while at 400° and 500° the sugar was almost entirely charred, and no trace of life observed. (It is a small black vibrio which resists the high temperature, and remains unaffected by all chemical solutions.)

The hay infusion was made by macerating hay in common water for one hour, filtering the liquor and leaving it exposed to the atmosphere all night, when it was sealed in the small tubes. The results were examined twenty-four days after being heated.

In this case, as in the sugar solution, life was observed in the solutions heated to 200° and 300° Fahr., while in those heated to 400° and 500° F. life was destroyed. In the solution not heated fungus matter was observed, while none appeared in any of the heated solutions.

A solution of gelatine of such strength that it remained liquid in cooling, was exposed to the atmosphere for twenty-four hours, and introduced into the small tubes which were sealed and heated. The fluids were examined twenty-four days after being heated.

The animalcules in this case were principally of a different class to those observed in the two preceding cases, and this class were injured at 100° Fahr. At 212° a considerable diminution in the amount had taken place, whilst at 300° all life was destroyed.

Water was placed in an open vessel, and a piece of meat suspended in it until it became putrid. This fluid was placed in the usual tubes heated, and the contents examined after twenty-four days. In this case life was still observed at 300° Fahr., while at 400° it had disappeared.

As previous experimenters have not exposed their solutions to so high a temperature as 300° Fahr., the life which they found was due to the development of germs remaining in the fluid.

Parts of the putrid meat solutions that had been heated were mixed with albumen, to ascertain whether they still possessed the power of propagating life, the result being that up to 300° Fahr. life and its germs had not been destroyed, whilst at 400° they had.

Putrid meat liquor was exposed for twenty hours to a temperature ranging from the freezing-point to 17° below that point. Immediately after melting the ice the animalcules appeared languid, and their power of locomotion was greatly decreased, but in two hours they appeared as energetic as before.

On Spontaneous Generation, or Protoplasmic Life. *By* F. Crace-Calvert, *F.R.S.*

The publication of Dr. Tyndall's paper on the abundance of germ-life in the atmosphere, and the difficulty of destroying this life, as well as other papers published by eminent men of science, suggested the inquiry if the germs existing or produced in a liquid in a state of fermentation or of putrefaction could be conveyed

to a liquid susceptible of entering into these states; and during the inquiry some facts were observed which I wish now to lay before you.

The first is the rapid development of germ-life. If the white of a new-laid egg be mixed with water (free from life), and exposed to the atmosphere for only fifteen minutes, in the months of August or September, it will show life in abundance; and to the want of a knowledge of this fact may be traced the erroneous conclusions arrived at by several gentlemen who have devoted their attention to the subject of spontaneous generation.

An essential point in the carrying out of such an investigation, was the preparation of pure distilled water. In distilled water prepared by the ordinary methods, I always found life after it had been kept for a few days; but by employing an apparatus through which a gas could be passed to displace the air, and adding to the water to be distilled a solution of potash and permanganate of potash, I obtained a water which, after three or four distillations, was found to be free from life. The gas employed in the first three series was hydrogen. The water was kept in the apparatus till wanted, to prevent any contact with air.

Water so distilled having been kept free from life for seventeen days, was introduced into twelve small tubes, and left exposed to the atmosphere for fifteen hours when the tubes were closed. Every eight days the tubes were examined; on the first and second examination no life was observed, but the third discovered two or three black vibrios in each field.

As this slow and limited development of life might be owing to the small amount of germs in the atmosphere, during the winter months a second series of experiments was made, placing the water in the tubes near putrid meat for two hours, at a temperature of 21° to 26° C. Six days after some of the tubes were examined and life observed, showing that by being placed near a source of protoplasmic life, the water had in two hours absorbed germs in sufficient quantity, for life to become visible in one fourth the time required in the first experiment; after six days a slight increase of life was noticed, but no further development could be afterwards seen.

The limited amount of life developed in pure water suggested a third series of experiments, in which albumen was added to the water. In this case life appeared in five days, and a considerable increase in ten. Albumen, therefore, facilitated the development of life.

The quantity of life produced in the above experiments being comparatively small, some fresh water was distilled, oxygen being substituted for the hydrogen in the apparatus; and a fourth series was commenced, which resulted in showing that although oxygen appears to favour the development of germs, it does not favour their reproduction.

When the weather had become much warmer and a marked increase of life in the atmosphere had taken place, some of the albumen solution employed in the above experiments was left exposed in tubes to its influence, when a large quantity of life was rapidly developed and continued to increase, proving the increase to be due not merely to reproduction, but to the introduction of fresh germs.

As no life appeared in that portion of the distilled water remaining in the apparatus before mentioned, which was examined from time to time, whilst it appeared in all the solutions made with it and impregnated by their exposure to the atmosphere, it is obvious that germs are necessary to the production of life.

On the relative Powers of various Substances in preventing the Generation of Animalcules, or the Development of their Germs, with special reference to the Germ Theory of Putrefaction. By Dr. JOHN DOUGAL.

On the advantage of Systematic Cooperation among Provincial Natural-History Societies, so as to make their observations available to Naturalists generally. By Sir WALTER ELLIOT, *K.C.S.I., F.L.S.*

Sir Walter stated that he had been led to consider the subject in the prepara-

tion of an address delivered to the Botanical Society of Edinburgh last November, in the course of which he attempted to show what contributions had been made by provincial societies to botanical knowledge and literature.

He found that the number of these societies had greatly increased of late years, and that they had done much useful and valuable work. This they publish in their own Proceedings or Transactions, the circulation of which is confined almost exclusively to their own members. The results of their labours are thus, in a great measure, lost both to their neighbours and to naturalists generally. After entering into some details of the subjects, illustrated by the Devonshire and Cornwall Societies, by the Berwickshire, Tyneside, Cotteswold, Woolhope, and other Field Clubs in their published 'Transactions,' many of the earlier volumes of which are so scarce as to be unprocurable by later members, he proceeded to show that this state of things had attracted the attention of others as well as of himself, and had given rise to a very general desire for greater unity of procedure. He concluded, therefore, that the time had come for taking action in the matter; and as the present occasion afforded an opportunity for discussing it with advantage, he invited the Section to take it up, with a view of eliciting practical suggestions (at the same time offering some himself) of such a nature as might be laid before the General Committee of the Association, and so enlisting the patronage of that body in its behalf.

The Origin and Distribution of Microzymes (Bacteria) *in water, and the circumstances which determine their Existence in the Tissues and Liquids of the Living Body. By* Dr. Burdon Sanderson, *F.R.S., and* Dr. Ferrier.

The paper read was an abstract of the chief results of an experimental investigation into the intimate nature of contagion published *in extenso* in the 'Thirteenth Report of the Medical Officer of the Privy Council.' It was considered necessary to examine the conditions of origin and life of microzymes in special reference to the phyto-pathological doctrines of Professor Hallier. In order to test the presence or absence of microzymes in contagious or healthy liquids and tissues, the method was adopted of cultivating these organisms in soils suitable for their growth, and under conditions favourable to their multiplication and development. By the enormous reproductive power of these organisms, and the changes which they induce in the organic liquids in which they are cultivated, the presence of microzymes can be most satisfactorily determined. The organic liquids employed as soils were chiefly Pasteur's solution and albuminous liquids, such as serum, &c. Before using these liquids as tests, however, it had first to be shown that they do not, in themselves, contain the conditions of evolution. For this purpose the liquids were introduced into capillary tubes, and investigated under the most varied conditions of exposure, temperature, and pressure.

The results of numerous experiments, lasting over several months, proved satisfactorily that when these liquids had been raised to a temperature of 150°–200° C., or even to 100° C., and carefully preserved from contact from air or surfaces which had not been superheated, no evolution of organic forms ever took place; while in the same liquids which had not been heated, but otherwise kept under exactly the same conditions, organisms were found in large numbers. The results were not modified by any variations in the tension of the air to which the liquids were exposed. Other experiments made with boiled and unboiled Pasteur's solution, introduced into glasses which had been previously heated, showed that fungi (*Torula* and *Penicillium*) appeared in unboiled solutions whether they were exposed or not, but much more abundantly when they were exposed than when they were protected with cotton-wool, and that in boiled solutions the growth of *Penicillium* was more luxuriant than in unboiled solutions under similar circumstances. *Bacteria* did not appear in the boiled liquids under any circumstances. *Bacteria* and fungi, therefore, seemed to differ in regard to their conditions of origin and growth. The result of numerous experiments demonstrated that the solutions in which microzymes appeared were those which had come in contact with surfaces which had

not been superheated, or had been contaminated by water which had not been boiled.

Bacteria were shown not to exist in the air under ordinary circumstances. Water was shown to be the primary source from which the germinal particles of *Bacteria* are derived, whenever they seem to originate in the organic solutions experimented with. This conclusion was satisfactorily demonstrated by impregnating organic solutions (which otherwise could be kept indefinitely barren of all organisms) with a drop or two of ordinary water, whereupon, in the course of a week, the development of *Bacteria* manifested itself in the clearest manner to the naked eye. This zymotic property (*i. e.* the faculty of determining the development of organic forms in a test solution to which it is added) is not possessed by all kinds of water in a like degree. Distinct degrees of opalescence (due to *Bacteria* chiefly) are manifested in Pasteur's solution when eprouvettes, charged with a given quantity of boiled Pasteur's solution, are impregnated with equal quantities of water from different sources.

Even ordinary distilled water was never found to be free from *Bacteria* germs. This was attributed to contamination with other water, or improperly cleaned receptacles. Filtration seems to have no appreciable influence on the zymotic property of water. From the most careful and repeated examination of water proved to be zymotic, it was found that such waters often contain no elements or particles which can be detected by the microscope. Experiments were made with optically pure water as in the sense used by Prof. Tyndall, or so nearly optically pure, that the electric beam in passing through it displays a blue colour; such water obtained by the fusion of ice was shown to be as zymotic as many other varieties of water, which in the beam are seen to be full of light-scattering particles.

Microzymes and their germs are deprived of vitality by thorough desiccation; they are likewise killed by permanganate of potash, ozone, carbolic acid in the proportion of ·5 per cent. of the liquid, sulphate of quinia in the same proportion, peroxide of hydrogen, and chlorine.

Torula and *Penicillium*, however, flourished in solutions which were fatal to *Bacteria*. When an albuminous or saccharine fluid is superheated (*i. e.* above 100° C.), it does not support microzyme life.

Experiments were made to determine whether the liquids and tissues of the living body participate in the zymotic property possessed by microzymes. It was shown that blood, fresh tissues, urine, milk, white of egg, pus from deep-seated abscesses, were free from microzymes, and further, that these tissues and fluids could be kept indefinitely free from all traces of decomposition if proper precautions were taken to preserve them from external contamination.

It was further shown that the slightest contact with ordinary water, or surfaces cleaned in the ordinary manner, was sufficient to set up septic changes in these tissues and liquids. It was therefore concluded that if microzymes are not the only cause of putrefaction, yet their presence is sufficient to set it up in liquids which otherwise manifested no tendency to septic changes. In regard to contagious liquids, few experiments had yet been made. Only in reference to pyæmic pus an experiment had been made; it was found full of *Bacteria*. From numerous facts and observations made during the progress of the inquiry, it was concluded that there is no developmental connexion between *Bacteria* and *Torula*, and that their apparent association is merely one of juxtaposition.

This conclusion is a direct contradiction to the botanical doctrines on which Hallier's theory of contagion is founded.

On the Establishment of Local Museums. *By* T. B. Grierson.

The establishment of local museums was pointed out as a means of giving a taste for learning and science to the people, for which, in the smaller towns and rural districts, there was no provision. Collections could readily be made; and in every district objects of interest would be met with, which a local museum would be the means of saving and bringing to light. Persons commissioned by scientific societies or one of the central institutions should make periodic visitations, and aid

by advice and otherwise. If an arrangement of this kind were extended all over the country, a knowledge of science would exist among the people, of which they are at present altogether destitute. The author entered upon some details of the system he proposed.

Botany.

On the Cultivation of Ipecacuanha in the Edinburgh Botanic Garden for transmission to India. By Professor Balfour, *F.R.SS. L. & E.*

Ipecacuanha is a valuable remedy for dysentery, and has been administered in large doses with decided benefit by medical men in India. The cultivation of the plant, however, owing to the rashness or carelessness of collectors and other causes, has failed to a certain extent in South America; and unless means can be taken for more extended cultivation, it seems probable that the quantity of Ipecacuanha might be insufficient for medicinal purposes, and its price might rise in the market to such an extent as to interfere with its general use. In these circumstances the Secretary of State for India (His Grace the Duke of Argyll) applied to the Directors of the Botanic Gardens in Britain with the view of ascertaining whether a sufficient stock of plants could be procured for exportation to India with the view of cultivation there for medicinal purposes. In the Edinburgh Botanic Garden there were some specimens of the plant which had been cultivated for forty years or more, and it was found by Mr. McNab that these could be easily multiplied by making sections of the root or rhizome. A description of the method pursued was read to the Botanical Society of Edinburgh, and separate copies were printed for the use of the India Office. The plant in the Garden was the same as that described by Sir William Hooker, and figured in the 'Botanical Magazine.' The supply from this source was obviously not sufficient for the purposes which the India Office had in view, and the time required for propagation would be too long. Accordingly, Professor Balfour and Dr. Christison wrote to a previous Graduate of the University of Edinburgh, Dr. Gunning, residing at Palmeiras, near Rio Janeiro, and induced him to take an interest in the matter. He entered cordially into their proposals, and very soon sent to the Botanic Garden boxes containing fresh plants. Although several of them suffered in the transit, owing to the mode of packing and the want of attention during the voyage, still a considerable number reached the Garden in a state fit for propagation after the method pursued by Mr. McNab. By this process a large stock of between 200 and 300 plants was secured. Of these, a considerable number have been transmitted to India successfully in a Wardian case. A figure of this case was given in Mr. McNab's published report. By the method employed, the small pots containing the plants were carefully secured, so that the case might even be turned upside down without injury*. The plant sent by Dr. Gunning differs in some particulars from that formerly in cultivation in the Botanic Garden, more especially as regards the form of its leaves. The old plant has leaves of a firmer texture, more or less elliptical, and somewhat wavy at the margin, and the stem suffruticose. The plant also flowers readily after a year's growth. The recent plant sent by Dr. Gunning resembles more the form figured by Martius. Its leaves are more delicate and pointed, its stem not so shrubby, and it has not yet produced flowers. There may be two varieties of the plant. The full determination of this must be reserved till the Rio Janeiro plants come into flower.

The drawings which were exhibited show the character of both varieties, so far as they can be at present represented from the specimens in the Botanic Garden. The drawings show the form of the leaves and stems, the character of the stipules and glands, the stomata and hairs of the leaves, and the microscopical structure of the stems and rhizomes.

The subject has been brought under the notice of the Meeting with the view of calling attention to the cultivation of a plant which, like Cinchona, is highly

* The case exhibited to the Meeting showed the arrangement.

valuable as a medicinal agent, and which, without due care and attention on the part of collectors, might ultimately become scarce or be eradicated in its native country.

On the Flora of Greenland. By Robert Brown, *M.A., Ph.D., F.R.G.S.*

An account of researches on the Phyto-geographical aspect of the Greenland flora compared with that of other portions of the arctic regions, the causes which conduced to it, and most general facts relating to the arctic flora, chiefly in relation to Dr. Hooker's classical memoir on the subject in the Linnean Transactions (vol. xxv.).

On the Geographical Distribution of the Floras of North-west America. By Robert Brown, *M.A., Ph.D., F.R.G.S.*

After studying the subject for nearly four years, during travels through all parts of the country to the west of the Rocky Mountains, Dr. Brown considered that instead of one homogenous flora in North-west America there are in reality five, viz. (1) The great flora of the region to the west of the Cascades and Sierra Nevada Mountains. (2) The flora between this range and the Rocky Mountains. (3) The Montane flora on the summits of the mountains about 4000 feet, chiefly arctic. (4) The flora of the Colorado descent. (5) The Athabascan flora, or the flora to the country.

On Specimens of Fossil-wood from the Base of the Lower Carboniferous Rocks at Langton, Berwickshire. By the Rev. Thomas Brown.

Suggestions on Fruit Classification. By Professor A. Dickson.

On the minute Anatomy of the Stem of the Screw-Pine, Pandanus utilis. *By* W. T. Thiselton Dyer, *B.A., B.Sc., Professor of Botany in the Royal College of Science for Ireland.*

Except that the tissues are less indurated, the general structure of the stem and the arrangement of the fibro-vascular bundles resemble that met with in palms. The bundles, however, are somewhat remarkable from containing vessels which belong to the scalariform type. In a transverse section these bundles are seen to become smaller towards the circumference and more condensed, forming a well-defined boundary to the narrow cortical portion of the stem. The bundles are, however, continued through the cortical portion, but are reduced to little more than a thread of prosenchyma. In the cortex there are numerous large cells containing raphides: these also occur in the rest of the stem, but are less frequent. Crystals of another kind are found in connexion with the fibro-vascular bundles. These are contained each in a square-shaped cell, forming part of a string or chain. A number of these strings or chains are distributed round the circumference of each fibro-vascular bundle; they are especially abundant in its cortical continuation, as they do not suffer a degradation proportionate to that of the other constituent tissues. This peculiar arrangement ot crystal-bearing cells seems probably unique. The crystals are four-sided prisms with pyramidal apices. They are almost certainly composed of calcium oxalate, though they are too minute and isolated with too much difficulty to allow of their satisfactory examination.

On the so-called 'Mimicry' in Plants. By W. T. Thiselton Dyer, *B.A., B.Sc., Professor of Botany in the Royal College of Science for Ireland.*

In all large natural families of plants there is a more or less distinctly observable general habit or *facies,* easily recognizable by the practised botanist. but not always as easily to be expressed in words. The existence of such a general habit in legu-

minous and composite plants is familiar to every one. What have been hitherto spoken of as *mimetic* plants are simply cases where a plant belonging to one family puts on the habit characteristic of another. This is entirely different from mimicry among animals, inasmuch as the resembling plants are hardly ever found with those they resemble, but more usually in widely different regions. *Mutisia speciosa* from Western South America, a Composite, has a scandent leguminous habit closely agreeing with that of *Lathyrus maritimus* of the European shores. In the same way three different genera of ferns have species (found in distant parts of the world) indistinguishable in a barren state. The term Mimicry seems objectionable in these cases, and the author proposes Pseudomorphism as a substitute. As to the cause of the phenomenon, he can only suggest that the influence of similar external circumstances moulds plants into the similar form most advantageous to them. An illustration is afforded by the closely resembling bud scales which are found in widely separated natural orders of deciduous trees as modifications of stipules. The author does not, however, think that the moulding influence need always be the same. He believes that different external conditions may produce the same result; in this respect they may be called analogous. Several identical plants are found on the sea-shore and also on mountains; perhaps the reason is that they are equally able to tolerate the effect of soda salts and also of mountain climate. The tolerance of either unfavourable condition gives them the advantage over less elastically constituted plants, and both are therefore analogous in their effects.

On Spiranthes Romanzoviana, *Cham.* *By* A. G. More, *F.L.S., M.R.I.A.*

In exhibiting some living specimens of this rare Irish orchid, Mr. More called attention to their delicious perfume. He had gathered the plant near Castletown, Berehaven, where it was in full flower about the 15th of July. It grows in grassy meadows, and also in rather boggy ground bordering on the sea, and is found in so many different fields that there is no present fear of its becoming extinct.

On Eriophorum alpinum, *Linn., as a British Plant.* *By* A. G. More, *F.L.S., M.R.I.A.*

Eriophorum alpinum had, a few years ago, been announced as an Irish plant on faith of some specimens forwarded to Dr. Moore by Mr. J. Sullivan of Cork, who reported that they had been gathered on the banks of a mountain-lake near Millstreet, county Cork. Subsequent investigation had, however, caused considerable doubts as to the correctness of this information; for both Mr. More himself and Dr. Moore had on two different occasions made a most careful search on the borders of Gurthavelia Lake without finding a trace of *Eriophorum alpinum*; and they now believe that *Scirpus cæspitosus*, whose spikes are often slightly woolly with the growth of the bristles, was gathered by the side of the lake, and probably some mistake was afterwards made in transmitting the specimens, which belong to the right plant.

With regard to the supposed Scottish locality in Sutherland, Dr. Balfour authorized him to say that he had always felt some slight doubt about the single specimen found in his herbarium; and this doubt was much increased on seeing the striking similarity of this specimen to others also belonging to the University Herbarium, and which were certainly collected in Forfarshire, rendering it highly probable that a piece of *E. alpinum* had by some accident been mixed with Dr. Balfour's specimens of *Scirpus cæspitosus*, or that a label had been inadvertently exchanged. Hence he believed that *Eriophorum alpinum* must, for the present, be erased altogether from the British flora.

On the Development of Fungi within the Thorax of Living Birds.* *By* Dr. James Murie, *F.L.S., F.G.S.*

The author referred to the circumstance of lowly organized vegetable structures

* This paper will be published in full, with a Plate, in the Trans. Roy. Micros. Soc., vol. vii.

being not unfrequently found growing in animals and man, both externally and internally. For the most part these affected the skin, giving rise to several cutaneous diseases. They also flourished in the alimentary canal; and among others, one peculiar form (*Sarcina*) had been described by the late Professor Goodsir from the human stomach. In nearly though not in all instances where vegetable organisms flourished within the living body, it was in organs where a certain amount of air had free access. It was more difficult to account for the cases where vegetable parasites arose in, so to speak, closed cavities. The instances which the author brought forward as coming under his observation were three in number, viz. a fungus-like growth in the abdomino-pleural membrane of a Kittiwake gull, *Rissa tridactyla* (Linn.), a great white-crested cockatoo, *Cacatua cristata* (Linn.), and a rough-legged buzzard, *Archibuteo lagopus* (Gm.). After a general description of the specimens in question, he referred to them as in some way bearing upon those doctrines whereby living organisms were supposed to originate out of the tissues themselves. Other weighty reasons undoubtedly might be given to the contrary; but as every fact, either furnishing doubtful evidence of, or opposed to the spontaneous generation theory, might be useful at the present juncture, the author thought a record of such worthy of being brought before the Association.

On the Changes which occur in Plants during the ripening of the Seeds, in order to ensure the access of the Air and Light as well as Heat, which are generally requisite for this purpose, without the loss of the Seeds before the ripening is completed. By J. BIRKBECK NEVINS, *M.D. Lond., F.B.S. Ed.*

In the poppy the capsule becomes erect because the valves are at the summit of the seed-vessel, whilst in Campanulaceæ the seed-vessels droop, because the valves are at the base of the capsule, except in the case of the *C. persicifolia*, which has an erect capsule, the valves being at the summit.

In the Primulaceæ the drooping flower becomes an erect capsule in ripening, except in the *Cyclamen*, which ripens its seed in the ground, and therefore droops until the capsule is buried in the earth, after which its capsule opens at its apex downwards. The *Anagallis*, which has always a closed seed-vessel, ripens with the capsule in various directions.

In the Stellarias, which are summer flowers, the flower is erect, as well as the capsules, the period of inflorescence being favourable to ripening. And in Composites, which flower in summer, the same is observed; whilst in the Coltsfoot and the African marigold, which ripen their seeds under difficulties, various changes of position occur, to shelter the immature seeds from injury from the weather. The Ranunculaceæ, Malvaceæ, Scrophulariaceæ, and several others were passed under review, and their various changes pointed out, which had the object in view of promoting the ripening of the seeds without premature loss from the seed-vessels.

On the Nature of the Cruciferous fruit, with reference to the Replum. By J. BIRKBECK NEVINS, *M.D. Lond., F.B.S. Ed.*

The replum is a direct prolongation of the stem, which produces the seeds without the intervention of carpellary leaves; as is also the case in the Coniferæ. After having produced the seeds, the stem bears two leafy organs, which are directed downwards, and adhere by their apices to the stem, below the point from which the seeds spring, and thus close in the seed-vessel, which therefore consists of a stem bearing the seeds (the replum) and two external leafy organs (the valves). When ripening commences, the apices of these deflected leaves separate from the stem, until at last they are entirely detached, and fall off at their articulation with the stem, leaving the seeds still adherent along the edges of the stem in four rows. The replum is therefore not a dissepiment derived in any way from the carpellary leaves, but simply a seed-bearing stem, flattened and thinned in the central part (the pith) until it is transparent. In accordance with this view, the venation of the valves is that of a leaf turned downwards, being directed towards the base of the

silicle, that is, according to this explanation, to the apex of the enveloping leaves. The term "false" dissepiment is therefore no longer necessary, the fruit being a normal growth, though of an unusual construction.

On the Species of Grimmia (*including* Schistidium) *as represented in the neighbourhood of Edinburgh. By* J. Sadler.

Observations on the intimate Structure of Spiral ducts in Plants and their relationship to the Flower. By Neil Stewart.

An Inquiry into the Functions of Colour in Plants during different Stages of their Development. By Neil Stewart.

On the Classification of the Vascular Cryptogamia, as affected by recent Discoveries amongst the Fossil Plants of the Coal-measures. By W. C. Williamson, *F.R.S., Professor of Natural History in Owens College, Manchester.*

The author described the structure of the stem of Calamite explaining, his interpretation of its structure, viz. that it consisted of a central fistular medulla, surrounded by a ring of woody wedges, each one of which grew by additions to the exterior of its surface until it often became a woody cylinder of considerable thickness. The *Lepidodendra* and *Sigillariæ* were next reviewed, beginning with *Lepidodendra*, in which the central axis was a mixture of cells and vessels surrounded by a very thin, and often scarcely appreciable ligneous ring, and which gave off vascular bundles to the leaves. Other forms were then noticed in which the central medulla became differentiated into a central cellular portion, and an outer vascular one, the latter existing as a modified medullary sheath. One of the types described by Mr. Binney as *Sigillaria vascularis*, exhibits these features; and the development was traced still further through *Diploxylon* and *Sigillaria*, where the woody zone became yet more fully developed, the medullary rays more distinct, and the differentiation of the two elements of the pith, viz. the vascular and the cellular, yet more complete. The origin of the vascular bundles going to the leaves in some forms of *Diploxylon* was shown to be, not in the medullary vessels, as described by Corda, but in a cellular layer separating the ring of the *medullary* vascular cylinder from the more external vascular cylinder of the true woody zone. The relation of these various structures to those seen in *Stigmaria* was pointed out. In the latter, as was to be expected in a root, the vessels of the medullary axis disappeared, the pith being in direct contact with the inner surface of the woody zone. The vascular bundles given off to the rootlets were shown to originate in the ligneous cylinder, and to pass outwards through large lenticular spores, occupied by mural cellular tissue, separating the woody wedges, whilst in addition to these spores, there exist a complete system of minor medullary rays, the entire structure exhibiting, in the author's opinion, an exogenous arrangement.

The conclusion to be drawn from the study of the structure of these fossil cryptogamic stems is, that, *so far as their medullary axis and ligneous zone is concerned*, they are not in any sense *Acrogens*, but Exogens; that they have a pith consisting of the less developed Lepidodendroid forms of a mixture of cells and vessels; that as we ascend in the series of forms the cells become separated from the vessels, the former occupying the interior, and the latter the exterior of the medullary axis; that the woody zone surrounding the medullary axis consists of a cylinder composed of radiating lines of vessels, which increase by successive additions to the external surface of the zone, the laminæ of which vessels are separated by mural arrangements of cellular tissue constituting two kinds of medullary rays; consequently when such a process of growth has gone on until the result was a tree with a stem two, three or more feet in diameter, the application of the term

acrogen becomes absurd. Such being the case, Prof. Williamson proposed to separate the vascular Cryptogams into two groups. The higher one, comprehending the Equisetaceæ, Lycopodiaceæ, and Isoetaceæ, to be termed the Cryptogamiæ Exogenæ, and which would form a connecting link between the Cryptogams and the true Exogenous plants through the Cycadeæ, and the other Gymnospermous Exogens. The lower one to be called the Cryptogamiæ Endogenæ, to comprehend the Ferns, which will unite the Cryptogams with the Endogens through the Palmaceæ.

Zoology.

Notice of two Specimens of Echinorhinus spinosus *taken in the Firth of Forth. By* Professor J. Duns.

On the Rarer Raptorial Birds of Scotland. By Professor J. Duns.

On the Carabus nitens *of the Scottish Moors. By* Dr. Grierson.

The Zoological Results of the Dredging Expedition of the Yacht 'Norna' off the Coast of Spain and Portugal in 1870. *By* W. Saville Kent.

The expedition was organized and superintended by Mr. Marshall Hall, the owner of the yacht, Mr. Kent accompanying him to supervise the collection and preservation of natural-history specimens, as also to report on all the novelties or objects of interest that might be obtained. The sponges collected during the expedition appear to have furnished the greater number of forms new to science, embracing more particularly many new representations of the group to which the beautiful *Euplectella*, or "Venus's flower-basket," and the "Glass-rope sponge," *Hyalonema*, belong, the latter, indeed, being amongst the spoils. All these forms were dredged in the deep-sea fishing ground, 400 to 800 fathoms, off Cezimbra, at the mouth of the Sado river; and from the same locality, with the assistance of the native fishermen, they had the good fortune to secure examples of several rare species of deep-sea ground sharks which frequent that coast line, including among others *Pseudotriakis microdon*, a species recently described by Professor Barboza du Bocage, of the Lisbon Museum. *Fusus contrarius* and a species of *Cassis* allied to *C. saburon* are among the rarer shells referred to by Mr. Kent, the former being interesting on account of its identity with a common fossil of the Norwich Crag, and the latter from its affinities with Japanese and Chinese species rather than with any known Atlantic or Mediterranean form. The occurrence in the same waters of a variety of *Hyalonema*, scarcely to be distinguished from the well-known Japanese *H. Sieboldi*, is also commented upon by Mr. Kent, as illustrating another instance of this singular distribution of allied species. Reviewing the whole amount of material collected during the cruise, Mr. Kent separates it into two portions, presenting respectively two entirely distinct facies. The first of these, including that collected from the shore line down to a depth of 100 fathoms, presents an interblending of Mediterranean species with those inhabiting our own more temperate coasts; while the remaining one, embracing all those acquired at a depth of from 400 to 800 fathoms, are remarkable for their boreal or cold-water area aspect and affinities, and in this respect, according to Mr. Kent, entirely supporting the deductions arrived at by Dr. Carpenter, from his extensive study of the fauna of these great depths in connexion with the expeditions of the 'Lightning' and 'Porcupine.' Among the more interesting Mediterranean forms taken, especial mention is made of *Dendrophyllia ramea*, a massive branching coral, not before recorded as occurring so far north, as also of various species of *Murex*, *Calappa granulata*, *Cestum veneris*, and other zoophytes usually supposed to

be restricted to the more southern arc. Mr. Kent expresses his hope that the entire success attending this cruise may influence other yacht-owners to follow the example of Mr. Marshall Hall, and, like him, to devote their craft for the portion of a season to scientific discovery, promising them they will find themselves more than compensated for the sacrifice of time or other interests it may involve by the fascinating nature of the work when entered upon, in addition to their thereby earning for themselves the lasting gratitude of the scientific world. The Royal Society granted £50 towards aiding in the necessary outlay in dredging and preserving apparatus. The paper constitutes a brief sketch of a report to be presented to the Royal Society by Mr. Kent.

A Proposal for a Modification of the strict Law of Priority in Zoological Nomenclature in certain cases. By W. A. Lewis.

On some recent Additions to the Arctic Fauna (a new Antipathes *and a new Apodal Lophioid). By* Dr. Christian Lütken.

On the occurrence of Brown Trout in Salt Water. By A. G. More, *F.L.S., M.R.I.A.*

In the sixth volume of his Catalogue of Fishes (Addenda, page 357), Dr. Günther has noticed the fact that *Salmo fario* frequently descends to the sea, and there "assumes a bright silvery coloration, with numerous x-shaped spots." The circumstance did not, however, seem to have met with so much attention as it deserves, and was very little known to anglers and fishermen. In Scotland, Mr. Peach, who had an extensive experience and knowledge of marine zoology, had assured him that no instance of the kind had come under his notice, save once, when he found a river-trout in the stomach of a cod-fish. But in the west of Ireland (in the counties of Donegal, Sligo, Limerick, and Kerry) Mr. More had ascertained, partly through others and partly from his own observation, that the river-trout in many places spontaneously frequents the salt water at the mouth of the rivers. The brown trout captured in salt water differ from their usual condition in having brighter and more silvery scales, something like those of the young salmon in the smolt condition; but he had not noticed any increase in the number of dark x-shaped spots. Mr. More would like it to be ascertained if these trout were brown trout "pure and simple," or hybrids. Specimens were exhibited.

On some Dredgings in Kenmare Bay. By A. G. More, *F.L.S., M.R.I.A.*

Mr. More exhibited a number of marine animals, which he had lately collected in Bantry and in Kenmare Bays, in the south-west of Ireland. Among them were *Amphioxus lanceolatus*, the lowest in organization of living fishes, a number of *Annelida* and *Ascidians*, &c.

On the so-called Tailless Trout of Islay. By C. W. Peach, *A.L.S.*

Mr. Peach stated that the trout he showed were sent to him by Mr. Colin Hay, distiller, of Ardbeg Islay, taken in Loch Namaorachin, about 1000 feet above the level of the sea; it is supposed to be the highest in the island. It is about an acre in extent, and so shallow that a man can wade through it; the bottom is quartz rock, like that of the mountains around it. Several other lochs are near it in which trout are plentiful, but none "tailless." So constant is this that Mr. McKay, a very keen fisher, has never for the thirty years of his fishing-experience in this loch taken any but "docked" ones. Mr. Peach further said that Mr. Hay was about to stock a loch at some distance from Loch Namaorachin with some of the "tailless" trout, in which, up to the present time, no trout have been taken, and thus to try whether this "docked" appearance will continue, and use other

means to work out as far as possible the history of this strange freak. He added that they could not be called altogether "tailless;" docked they may be, from not having a vestige of the external caudal fin-rays. The fish were in splendid condition, and the whole of the other fins perfect; and in every other respect nothing was wanting, as could be seen by the specimens shown, and by the beautiful skeleton of one prepared by Mr. Stirling, assistant to Professor Turner*.

On the Hydrographical System of the Freshwater Fish of Algeria. *By* Colonel Playfair.

Remarks on a favourable occasion for the establishment of Zoological Observatories. *By* P. L. Sclater, *M.A., Ph.D., F.R.S.*

After alluding to the report of the Committee of the British Association for the establishment of zoological observatories, which had been read by the author at a previous meeting of the Section, attention was called to the fact that a very favourable opportunity for the establishment of three zoological observatories in very little-known parts of the globe would shortly present itself, and it was greatly to be hoped that advantage would be taken of it.

On the occasion of the transit of Venus in 1874, the Astronomer Royal proposes to organize observing-expeditions to the following five stations:—(1) Oahu, Sandwich Islands, (2) Kerguelen's Island, (3) Rodriguez, (4) Auckland, New Zealand, (5) Alexandria. At the first three of these stations (Oahu, Kerguelen's Island, and Rodriguez) it would be necessary to have a corps of scientific observers resident for twelve months previous to the transit, in order that the absolute longitudes of these places, which were not correctly known, might be obtained. The author pointed out how little was yet known of the terrestrial and marine zoology of these three islands, and specified various particulars, in the case of each of their faunas, which it would be especially desirable to investigate. He then urged that the addition of one or more zoological collectors, or observing-naturalists, to the corps of astronomical observers in each of these stations would occasion very slight additional expense, and suggested that application should be made to the Government to permit such naturalists to accompany these expeditions, and to undertake the necessary expenditure.

Dr. J. A. Smith exhibited the Skull of an Elk found in Berwickshire.

On the Structure of Crinoids. *By* Professor Wyville Thomson, *F.R.SS. L. & E.*

On the Palæontological Relations of the Fauna of the North Atlantic. *By* Professor Wyville Thomson, *F.R.SS. L. & E.*

On a curious South-African Grasshopper, Trachypetra bufo† (White), *which mimics with much precision the appearance of the stones among which it lives.* *By* Roland Trimen, *F.L.S., F.Z.S.*

He commenced by remarking that some tendency existed to separate too widely those cases of mimicry where one animal imitated another, from those

* Since the paper was read Mr. Peach had learnt that this want of caudal fin-rays has not been occasioned by lead-poisoning; for not a particle of lead is to be found in or near the loch. In a loch on the island about 6 miles from Loch Namaorachin trout are found plentiful; this loch is in a limestone basin, and lead is abundant in it; and here all the trout have perfect tails, and all the other fins in fine condition.

† Methuen's 'Wanderings in the Wilderness,' 2nd edit. 1848. Appendix, p. 362, pl. ii. f. 3.

in which an animal closely resembled either some part of a plant or some inorganic object; and expressed the opinion that these two sets of cases were wholly one in kind, the evident object in all being the protection of the imitator. Describing a visit paid to the vicinity of Grahamstown in search of this insect, he observed that it was a work of considerable difficulty to distinguish the grasshoppers from the stones, and he was engaged for half an hour in careful search over a known station of the species before discovering an example. He noted the further most interesting fact, that, in certain spots (often only a few square yards in extent) where the stones lying on the ground were darker, lighter, or more mottled than those generally prevalent, the *Trachypetra* found among such stones varied similarly from the ordinary dull ferruginous-brown colouring in imitation of them. It was pointed out that the close imitation of the stones was mainly effected by the modification of the dorsal shield of the prothorax, which is (with the whole thorax) much flattened and widened, and is further much produced posteriorly, and has its surface roughened or granulated in close resemblance to the surface of the stones.

In conclusion, he called attention to the bearing of the case of this insect on the question of the origin of species; and in putting the alternative whether the peculiar station of the *Trachypetra* had been specially prepared for it immediately before or simultaneously with the creation of the insect, or whether, on the contrary, the insect had been very gradually modified by natural selection in imitation of the stones for the purpose of concealment, he expressed his decided opinion in favour of the latter hypothesis.

Specimens of the insect were exhibited in association with some of the stones among which they were captured; and the very close resemblance between the stones and the insects was very obvious. Mr. Trimen observed that in nature the mimicry was more effective, the colours of the dead insects having faded considerably, and the shrinking of the abdomen having caused the hind legs to be much more apparent than was the case in living examples.

Les Chauves-souris de l'époque du Mammouth et de l'époque actuelle. *Par* Professeur VAN BENEDEN.

La théorie de Darwin est, dit-on, une véritable conception scientifique, fondée sur la concurrence vitale et la sélection naturelle. L'évolution naturelle des formes est pour le savant illustre le résultat de la lutte pour la vie et de la survivance des plus forts.

Si les animaux subissent la loi de cette concurrence vitale et de la sélection naturelle, il faut se demander quel est l'effet de cette influence pendant la période actuelle.

Pendant ce long laps de temps qui nous sépare de l'âge du Mammouth et de l'Ours des cavernes, quelles sont les modifications qui sont survenues dans le nombre comme dans les caractères des espèces? S'aperçoit-on des effets de la lutte pour la vie et, comme conséquence, de la survivance des plus forts? C'est la question que nous avons voulu examiner.

On est généralement d'accord sur ce point que, pour expliquer les phénomènes des temps géologiques, il faut chercher la solution dans les phénomènes de l'époque actuelle. Ce qui se passe sous nos yeux doit nous faire comprendre ce qui s'est passé antérieurement.

C'est cette pensée que vient d'exprimer avec tant d'élégance l'illustre Président de l'Association, Sir William Thomson, dans son discours d'ouverture: L'essence de la science consiste à déduire de phénomènes actuellement soumis à l'observation l'état antérieur des choses, et à préjuger leurs évolutions futures.

Nous avons été conduit à nous occuper de ces questions à la suite de recherches sur les parasites des Cheiroptères (Chauves-souris) et d'explorations faites dans les cavernes. Nous avons comparé des animaux, vivant autour de nous et dans nos grottes, avec ceux qui hantaient autrefois ces mêmes lieux à l'époque où les Ours et les Rennes remplissaient ces retraites de leurs dépouilles.

L'on sait que les ossements qui sont enfouis avec ceux des Ours appartiennent à trois catégories d'animaux: la première comprend ceux qui ont disparu de nos

contrées et qui ont émigré ; la seconde ceux qui sont restés en vie dans les mêmes localités; la troisième ceux qui ont disparu et que l'on ne connaît que par leurs dépouilles plus ou moins bien conservées. Toutes les espèces de grande taille ont quitté ces lieux et appartiennent à la première et à la troisième catégories. On peut dire que c'est la présence de l'homme qui les a éloignés. Les petits seuls ont continué à vivre à côté de l'homme. L'homme est le maître des grands, mais il subit la loi des petits. Nous faisons fuir l'Éléphant et le Lion, mais nous ne parvenons pas plus à chasser les Rats et les Souris que les parasites du corps ou les infusoires de l'eau et de l'air.

Les petites espèces qui ont continué à vivre dans nos contrées sont, les uns herbivores, les autres carnassiers ou insectivores.

Parmi les carnassiers se trouvent le Loup, le Renard, le Blaireau, la Loutre, la Fouïne, le Putois, la Belette ; parmi les insectivores, indépendamment du Hérisson, de la Taupe et des Musaraignes, les différentes espèces de Chauves-souris.

Ce sont ces derniers Insectivores que nous avons choisis pour élucider la question qui nous occupe. Les Chauves-souris sont en effet les plus propres à cette étude, puisqu'elles sont soumises toutes au même régime, qu'elles ont le même genre de vie, et que, plus que tout autre animal, elles sont complètement sous l'influence des changements de température. Nulle part la concurrence vitale n'a dû être plus puissante que chez des animaux qui ont dû traverser des périodes de froid et qui ne trouvent des insectes pour pâture, qu'à l'époque des chaleurs. D'autre part, il n'y a pas d'animaux, vivant autour de nous, aussi complètement indépendants que les Chauves-souris, et, par conséquent, plus propres à subir les effets de la sélection *naturelle.*

Schmerling avait déjà trouvé de nombreux restes de ces animaux, à côté des ossements d'Ours, de Lion, et de Renne, mais il n'a pas eu le temps de distinguer les espèces et de les comparer. Nous avons pu combler cette lacune et compléter ces recherches par les observations que nous avions en porte-feuille sur les Chauves-souris des grottes de Furfooz.

Nous pouvons garantir avec Schmerling que les os de Chauves-souris que nous avons recueillis, sont fossiles au même titre que les autres animaux enfouis, et que leur enfouissement date de la même époque.

Nous avons fait des recherches sur les diverses espèces qui vivent dans les cavernes ; nous avons étudié chaque espèce, et préparé leurs os en tenant compte de l'âge et du sexe, et nous avons réuni tout ce que les explorations ont pu nous fournir pour la comparaison ; il est résulté pour nous de l'étude comparée des espèces vivantes et fossiles, que les Chauves-souris qui vivent aujourd'hui dans les grottes, sont exactement les mêmes que celles qui y vivaient à l'époque des Ours, et que les mêmes espèces y ont conservé leur demeure les unes à côté des autres sans le moindre changement. Dans tel endroit on trouve principalement le *Grand fer-à-cheval* (*Rhinolophus ferrum-equinum*), dans tel autre endroit *le Petit fer-à-cheval* (*Rhinolophus hippocrepis*) ; ici c'est le *Dasycnème* (*Vespertilio dasycnemus*), là c'est le *Mystacin* (*Vespertilio mystacinus*), le *Murin* (*Vespertilio murinus*) ou *l'Oreillard* (*Plecotus auritus*). Si les eaux envahissaient aujourd'hui, comme elles l'ont fait autrefois, la retraite de ces animaux, et que leurs ossements fussent conservés, on trouverait dans le limon exactement les mêmes espèces qu'autrefois.

Elles sont tellement semblables les unes aux autres, que celles qui se trouvent le plus abondamment aujourd'hui, sont aussi celles qui ont laissé le plus de débris.

En un mot, aucun changement n'est survenu dans les diverses espèces de Chauves-souris. La concurrence vitale n'a produit d'effet ni sur le nombre ni sur la taille ; tous ces animaux sont restés exactement ce qu'ils étaient à l'époque où l'Ours foulait notre sol à côté du Mammouth et du Renne.

Que l'on compare entr'eux les os des grandes espèces ou des petites, des fortes ou des faibles, on voit qu'elles se sont toutes maintenues dans les mêmes conditions ; chaque espèce a sa manière de faire la chasse, choisit les lieux et le moment de s'y livrer, et conserve sa place au crépuscule.

Et ce que nous observons dans les Chauves-souris, nous le constatons également pour tous ceux qui ont vécu à côté d'eux : les mollusques terrestres n'offrent pas plus de différence si on les compare avec ceux d'aujourd'hui, que les poissons, les reptiles les oiseaux ou les mammifères.

La concurrence vitale existe, mais la lutte entre individus ne produit aucun effet sur l'espèce; la sélection naturelle conduit, d'après nous, non à l'altération insensible des types spécifiques, mais, au contraire, à la conservation du moule de chacun d'eux dans toute sa pureté.

Que l'on compare cent têtes de Renard, de Putois ou de Fouine, animaux abandonnés complètement à leur libre instinct, c'est à peine si, en tenant compte de l'âge et du sexe, on trouve quelque différence. La taille même est parfaitement semblable. Que l'on compare au contraire cent têtes d'animaux domestiques, d'animaux qui ont subi la contrainte de l'homme, qui ont été sous le joug de la sélection *artificielle*, qui ont accepté la nourriture et le gîte sans faire choix à l'époque du rut et il n'y aura pas deux têtes semblables.

La sélection naturelle, loin de produire des modifications qui amèneront la formation d'espèces nouvelles, n'a d'autre effet, à notre avis, quand elle est vraiment naturelle, que la conservation du type dans toute sa pureté primitive. L'instinct qui pousse chaque espèce à l'accomplissement de ses fonctions est la sauvegarde de sa conservation.

Nous terminerons, en faisant remarquer que si les animaux qui ont été aussi complètement soumis à l'influence de *la concurrence vitale* et de la *sélection naturelle*, depuis l'époque du Mammouth et de l'Ours des cavernes jusqu'au jour d'aujourd'hui, si ces animaux, disons-nous, après ce long laps de temps ne présentent aucun changement, aucune modification, ni dans le nombre, ni dans la forme, ni dans la taille, nous nous demandons si on est en droit d'invoquer la loi de sélection basée sur la concurrence vitale pour expliquer la formation des espèces. Nous le répétons, une théorie, pour être scientifique, doit être basée sur des phénomènes qui s'accomplissent dans les temps actuels, et dont nous pouvons être témoins.

Il ne sera pas hors de propos de faire remarquer qu'à une époque géologique de la période primaire, un fait analogue a été observé par le naturaliste le plus autorisé peut-être qui a écrit sur les Trilobites. Sur 350 espèces de Trilobites, dit M. Barrande, dans un résumé de ses travaux sur ce groupe intéressant d'animaux, dix sont variables, mais ces variations ne portent que sur la taille, la grosseur des yeux, le nombre correspondant des lentilles, le nombre d'articulations visibles au *Pigidium* et le nombre de pointes ornementales.

Ces variations sont purement temporaires, et M. Barrande a constaté dans la plupart des cas, le retour à la forme typique ou primitive. Les variations ne semblent être que des oscillations transitoires.

Aucune des 350 espèces n'a produit une nouvelle forme spécifique distincte et permanente. Les traces de *transformation par voie de filiation* sont complètement imperceptibles.

Plusieurs zoologistes et paléontologistes qui se sont occupés d'autres groupes, et d'autres époques géologiques, sont arrivés au même résultat après de longues recherches et de patientes comparaisons.

Le même phénomène se présente donc à l'époque primaire et à l'époque actuelle, et nous ne voyons pas que la concurrence vitale et la sélection naturelle aient produit quelque part une nouvelle forme que l'on soit en droit de considérer comme le résultat de la filiation.

Notes on Dredging at Madeira. By the Rev. R. B. Watson.

Anatomy and Physiology.

On the Pressure of the Atmosphere as an Auxiliary Force in carrying on the Circulation of the Blood. By Professor A. Buchanan.

The author holds that the pressure of the atmosphere, rendered effective by the dilatation of the chest and of the heart, is an auxiliary to the propulsive force of the heart so indispensable, that without it the circulation of the blood cannot go on for more than three and a half minutes.

The author described two experiments bearing on this subject. The apparatus required for each of them is an elastic bulb, furnished with valves, which enable it to act like a pump. To the opening, by which the liquid enters, there is attached a flaccescent tube, such as a portion of a sheep's intestine. If the extremity of this tube is dipped into water, and the pump, held vertically, is set into action, no water rises in the tube. This is Dr. Arnott's famous experiment, which led him to declare that "it is a physical impossibility that a sucking action of the chest or heart can be a cause of the blood's motion in the veins." Dr. Arnott's interpretation of this experiment has caused the doctrine advocated by the author to be ostracised in this country.

In the second experiment the action of the pump is assisted by that of a column of liquid, which is obtained by attaching the free end of the intestine to an aperture in the bottom or side of the water-cistern, and keeping the pump constantly beneath the level of the water. The pump was now shown to act with the most perfect facility, and without any risk of the collapse of the intestine, which is kept constantly distended by the pressure of the column of water. The author argued that the blood-vessels are in like manner kept distended by the pressure of the blood resulting from the propulsive force of the heart, and explained that if the column of water were about ten inches in height, it would then exert a force equal to the distending force with which the veins entering the chest are kept patent by the force of the heart.

The author then proceeded to illustrate his theory by reference to the phenomena attendant upon inspiration and expiration, the pulse, the condition of the fœtal circulation, and asphyxia.

An Experimental Inquiry into some of the Results of Inoculation in the lower Animals. By John Chiene, M.D.

The author related shortly the results of a series of experiments in which rabbits were inoculated with cancerous matter obtained from the human subject. In the great majority of cases the matter was introduced below the skin. The general result of the investigation may be summed up as follows:—In rabbits the inoculation of cancerous matter, obtained (1) from post-mortem examinations, (2) from tumours removed by the surgeon, (3) directly from the growing tumour during life, does not produce cancer, but a local form of cystic formation of a scrofulous type, which does not materially differ from the appearances seen after inoculation of the rabbit with tubercle, or after the introduction of any irritant. Subsequent disease of internal organs is rare. The local disease has a tendency to heal either by contraction or by suppuration. In no case did death follow as a result of the inoculation. In two cases in which rabbits were inoculated from a lymphoma, both died in consequence of the virulence of the local inflammation, which was accompanied by the deposit of a large cake of cheesy matter.

On the Composition of the Carpus of the Dog. By Professor W. H. Flower, F.R.S.

This communication was illustrated by the exhibition of the bones of the carpus of a dog, six weeks old, in which the so-called *scapho-lunar* bone consisted of three distinct ossifications, one corresponding to the *radiale* or scaphoid, one to the *intermedium* or lunar, and one to the *os centrale* of the typical carpus. The same arrangement was found on both sides of the body. It is different from what has previously been observed, and shows that in some of the Carnivora at least neither of the three above-named elements of the normal carpus are suppressed; neither are they connate, but they are all developed independently, and afterwards coalesce to form a single bone.

On the Magnetic and Diamagnetic Properties of the Blood. By Dr. Arthur Gamgee.

On the Uses of the Uvula. *By* Sir Duncan Gibb, *Bart., M.D.*

The author commenced by saying that the true functional uses of the uvula had never been wholly understood, and then entered into a description of its composition, situation, and relation to neighbouring muscles. Anatomists describe the action of the uvular muscle as an elevator, and as therefore shortening the uvula. It is, however, a sentinel to the fauces, especially in the act of deglutition; for when any substance comes into contact with it, it excites the action of all the neighbouring muscles until that is got rid of. But it possesses a function of not less importance in holding the soft palate tense and firm in the medial line against the wall of the pharynx during the act of deglutition itself, and thus prevents the passage upwards of fluid or solid substances behind the nose. This was supported by experiments upon a person who had lost the bones of the nose, permitting of a view of the action of the soft palate from its nasal aspect during deglutition, with or without food. Under either circumstance, a double arch was seen in the form of two convex swellings, held in a state of firm tension by the action of the uvula pressing down the centre of the soft palate, with its end resting flat against the wall of the pharynx. There was the *motor uvula* muscle situated superficially, like a distinct band, tied round the soft palate in its most important resisting part, to prevent the possibility of food passing upwards, and in this it was supported coordinately by all the neighbouring muscles concerned in the act of deglutition. There also was a fact not previously known—viz. the action of the uvula as a *point d'appui* in holding the soft palate tense in the middle line against the pharynx during deglutition, at the same time that the muscle acted as a compressor of the soft palate itself. Its tension ceased the moment that the constrictors of the pharynx had fully exerted their influence over the substances swallowed. Whilst the uvula has its special uses in the act of deglutition, it exerts a not less decisive influence upon the voice when uttered in a very loud tone, or in singing the higher registers, in both sexes; then its character as a levator or shortener is exerted. If this power is impaired by removal of the muscular (not the membranous) end, then the singing powers are damaged. The author now described the appearance and action of the uvula as seen in singing the higher notes, its point becoming almost invisible, and the soft palate being drawn backwards and upwards, diminishing the space between it and the wall of the pharynx. The movements of the uvula are exceedingly rapid, and vary with the continuous or quavering character of the singing notes. In the shakes of the voice it is seen to be undergoing a series of short ups and downs, at every inspiration descending, and then rapidly ascending, and keeping up until the note, prolonged or otherwise, is finished. Some remarks were made upon elongation of the uvula and its effects, a distinction being made between its elongated membranous end and the true muscular tip which should not be meddled with. Speech, the author said, was modulated by the soft palate and uvula, and the motor power of the latter is unquestionably exerted in pronouncing the letters K, Q, and X, with their associations, more especially the gutturals of the various languages. He summed up the uses of the uvula as follows:—"1. It acts as a sentinel to the fauces in exciting the act of deglutition when anything has to be swallowed. 2. It compresses the soft palate and holds its posterior free border firmly against the wall of the pharynx in deglutition, so that nothing can pass upwards. 3. It modifies speech in the production of loud declamation and the guttural forms of language by lessening or diminishing the pharyngo-nasal passage when it acts as an elevator. 4. Its elevating power is increased to the most extreme degree in the highest ranges of the singing voice, and is very moderately exerted in the lower ranges. 5. Therefore, in its uses, deglutition and vocalisation are the functions that are intimately associated with the uvula, and both become impaired more or less if it is destroyed, wholly removed, or seriously injured."

On some Abnormalities of the Larynx. *By* Sir Duncan Gibb, *Bart., M.D.*

The author described a rare instance of absence of both arytenoid cartilages in a girl of eighteen. Likewise one in which the epiglottis possessed the shape of a trefoil leaf, and two others in boys of fissure of the same cartilage.

All these were congenital, and were explained by means of diagrams.

On the Caudal and Abdominal Muscles of the Cryptobranch. By Professor HUMPHRY, *F.R.S.*

On the Existence of Hæmoglobin in the Muscular Tissue, and its relation to Muscular Activity. By E. RAY LANKESTER.

The author demonstrated to the Section, by means of the spectroscope, that hæmoglobin existed in certain muscles of the gasteropodous mollusks, viz. the active muscles which move the lingual ribbon and lips; at the same time the *blood* of these gasteropods is entirely devoid of hæmoglobin, being colourless. This was considered a proof of the functional relation of hæmoglobin to muscular activity, and coincided with the results attained by Ludwig, who demonstrated the absolute necessity of the presence of oxygen in a muscle in order that it should be active; the hæmoglobin, by its oxygen-seizing power, acts in the same way for the muscular respiration as it does in those exceptional invertebrata which, living in foul conditions, are, as the author showed, provided with hæmoglobin in their blood, thus being enabled to accumulate what little oxygen there is present.

On the Ciliated Condition of the Inner Layer of the Blastoderm in the Ova of Birds and in the Omphalomesenteric Vessels. By B. T. LOWNE.

On the Bearing of Muscular Anomalies on the Darwinian Theory of the Origin of Species. By Professor A. MACALISTER, *M.D.*

On a New Form of Tetanometer. By Dr. M'KENDRICK.

On the Nutrition of Muscular and Pulmonary Tissue in Health and in Phthisis, with Remarks on the Colloid Condition of Matter. By WILLIAM MARCET, *M.D., F.R.S., late Senior Assistant Physician to the Hospital for Consumption and Diseases of the Chest, Brompton, and to the Westminster Hospital, London.*

The author sums up the conclusions at which he has arrived as follows:—

1. Phosphoric acid and potash may be prepared artificially in the colloid state by dialyzing a mixture of chloride of potassium and phosphate of soda.

2. Wheaten flour, potato, and rice are found to contain respectively nearly the same proportions of colloid phosphoric acid and colloid potash compared to the total quantities of these substances present; and these same proportions of phosphoric acid and potash are occasionally found to exist also in blood.

3. Plants form colloid material, although they may find some ready prepared, or in process of preparation, in the soil.

4. Muscular tissue in health is formed of three classes of substances: 1st, those which constitute the tissue proper; 2nd, those destined to become transformed into the tissue proper and make up for the waste; 3rd, those which are in process of elimination. The first are solid and colloid, the second fluid and colloid, and the third fluid and crystalloid; the phosphoric acid and potash in the 3rd class of substances occurring precisely in the proportion required to form crystalloid pyrophosphate of potash. This is invariably true for the flesh of oxen, but in the salmon the proportions do not quite agree with those of the above compound, which appears to show that the material in progress of elimination is somewhat less crystalloid in fishes than in the flesh of the higher animals; and this would account for an accumulation of effete matter in the salmon.

5. The blood-corpuscles appear to take up albumen, phosphoric acid, and potash

in the blood, and yield them in the proper proportions to muscular tissue for its nutrition; but this subject requires further investigation.

6. The nutrition of pulmonary tissue in health differs from that of muscular tissue, inasmuch as the proportion of phosphoric acid to the albumen in the tissue proper, and consequently also in the nutritive material, is much higher in the lungs than in flesh, and that of the potash in the effete material is much higher proportionally to phosphoric acid in pulmonary than in muscular tissue. This excess of potash is apparently eliminated under the form of carbonate.

7. The nature of the chemical changes which take place within muscles in consumption is the same as in health; but these changes are lessened in degree, the amount of nutritive material supplied being diminished. Moreover, there appears to be in muscular tissue in phthisis a beginning of that separation of water from the solids which, under other circumstances, only occurs some time after death.

8. Muscular tissue in consumption contains more soda and chlorine than in a state of health, in the mean proportion of 0·117 of chlorine, and 0·239 of soda in health, to 0·385 of chlorine and 0·446 of soda in consumption for 200 grammes of flesh, showing apparently that the physical power of diffusion, which had been kept in abeyance in health, begins to act in phthisis.

9. The pulmonary organ in phthisis, when consolidated and softening, still undergoes a process of nutrition; but this phenomenon is different from that which occurs in health, and becomes remarkably like the nutrition of muscular tissue.

10. The pulpy state of the pulmonary tissue in the cheesy or softening condition, appears to be due to an altered relation between the water and solids, the colloid condition of the tissue being either lost or considerably diminished. The diseased organ, moreover, contains less colloid and more effete or crystalloid material than it does in health, these several phenomena showing, as in the case of muscles, a commencement of physical change.

11. Finally, death from consumption, when not due to asphyxia from deficient action of the organs of respiration, is apparently owing to the physical power of matter overcoming the phenomena of life, the nature of which is still a mystery, physical changes actually commencing before life is extinct.

A Model of the Circulation of the Blood, by Professor Rutherford, was exhibited.

Dietaries in the Workhouses of England and Wales. *By* Dr. Edward Smith, *F.R.S., Medical Officer of the Poor-law Board.*

The author referred to the fact that schemes of dietary are agreed upon by the combined action of the local authorities, viz. the guardians of the poor, and the central authority; and showed that, as the dietary should correspond with that of the labouring classes, it must vary in different localities, and be based upon local knowledge. The dietary is thus prepared by the guardians and examined and sanctioned by the Poor-law Board. He explained the steps which have recently been taken by the latter to give advice to the former and to establish greatly improved dietaries. This was initiated by the Rt. Hon. C. P. Villiers, who first made the appointment of medical officer to the Board, and carried into effect by the Earl of Devon and his successors as Presidents of the Poor-law Board. It is now laid down by that authority that the foods to be selected shall be those in ordinary use in the several localities, and that the kind and quantity of food shall be adapted to the wants of the several classes of inmates. The chief differences of food are found in the quantity of meat supplied and the mode in which it is served, and in the use of oatmeal, cheese, milk, and puddings. On many of these points the dietaries in Dorset and Westmoreland were contrasted. Thus he showed, from inquiries made by him for the Government some years ago, that the quantities of food obtained by the working classes per adult weekly were, in Dorset—bread stuffs, 13 lb.; sugars, $3\frac{1}{4}$ oz.; fats, $4\frac{1}{4}$ oz.; meat, $7\frac{1}{4}$ oz.; milk, 12 oz.; and cheese, $12\frac{1}{2}$ oz.; while in Westmoreland the quantities were,—bread stuffs, $12\frac{1}{2}$ lb.; sugars, $10\frac{3}{4}$ oz.; fats, $6\frac{3}{4}$ oz.; meat, $21\frac{1}{2}$ oz.; milk, 120 oz.; and cheese, 2 oz. He then showed what is the typical diet of children at various ages, and for able-bodied and aged

adults, and the quantity of the several foods allowed in workhouses. Children under two years of age get milk, bread, and rice-pudding daily. From two to five years, pudding on three days, meat and potatoes on three days, and soup or other food on one day. From five to nine years there is one other day of meat and potatoes, and commonly one of soup instead of pudding. From nine to sixteen that of adults. For able-bodied, bread and gruel at breakfast and supper, varied by broth or cheese in the several localities; at dinner, meat in some form on four days, and pudding or cheese on three days. For aged, tea and bread and butter at breakfast and supper; at dinner, meat in some form on five days, with pudding or cheese or other food on two days. The standard of measurement of the sufficiency of this food is that which he gave to the Government when advising on the Lancashire cotton-famine, viz. 4300 grains of carbon and 200 grains of nitrogen daily; and the model dietary which he had framed for workhouses in the Midland Counties supplied more than this to the adults. He then pointed out that, whilst the above-mentioned quantity of food supported the health and strength of the inmates, except perhaps as regards children, there are still many workhouses where the dietary is very unsatisfactory. In some, gruel and bread are given at breakfast and supper to nearly all the inmates, or where meat in a separate form is not given, or where a very small quantity, as 2 oz. or 3 oz. of raw meat was allowed two or three times a week, or where bread and cheese alone are given to some classes in eighteen out of twenty-one meals weekly, or where soup containing no meat is given thrice a week, or where meat when given is given only when cold; whilst, on the other hand, there are workhouses in the manufacturing districts where meat and bread are given in great excess. He was of opinion that the time may arrive when the Government will prepare several schemes of dietary for different parts of the country; but in the meantime improvements are now in rapid progress. He exhibited tables showing the quantities of food taken by the working classes in every county of England and in Wales, and the dietary which he had recommended for use in workhouses in the Midland Counties; and he also read the details of the dietary which Professor Christison had devised for the Edinburgh charity workhouse in 1854, supplying oatmeal and buttermilk at breakfast and supper, and meat soup with bread at dinner.

On some Rudimentary Structures recently met with in the Dissection of a large Fin-Whale. By Prof. STRUTHERS.

The whale was a specimen of the Razorback (*Balænoptera Musculus*), 64 feet in length. It was found dead in the North Sea, off Aberdeen, and towed into Peterhead. Searching for a rudiment of the hind limb, the author found it represented by a bone attached by ligaments to the external process of the pelvic bone. He found a sixteenth pair of ribs. The first rib had articulated to it a capitular process 4 to 5 inches in length. The flexor and extensor muscles of the fingers were carefully dissected. The muscles found were the homologues of the following muscles in man:—flexor carpi ulnaris, flexor profundus digitorum, flexor longus pollicis, extensor communis digitorum. The flexor carpi ulnaris was inserted into a distinct and moveable pisiform cartilage. These muscles the author regarded as rudimentary structures, whose function was not extinct but low; not to be explained by notions of final cause or of so-called type, but by inheritance and the influence of function; the one, as part of a great scheme of evolution, accounted for their existence, the other, by fitness and use, had preserved them from becoming extinct.

On the Cervical Vertebræ in Cetacea. By Prof. STRUTHERS.

The paper was directed chiefly to the consideration of the various conditions of stiffness and mobility of the vertebræ, and the various degrees of development of the transverse processes. The seven vertebræ were present as a mammalian affinity, and their conditions are modified by function. The surgeon gives his patient a moveable or a stiff joint according as he desires, by practising either rest or motion, and the same law would no doubt act in the whale's neck. The great ring of the transverse processes contains a large vascular plexus, as it contains an artery in

man; but that is not its meaning. It is the walls of the ring which are developed for ligamentous and muscular attachments. The lower processes he divided into three stages, and compared these to three stages of the corresponding parts in man. The ligaments between the axis, atlas, and occiput had been dissected, and he demonstrated their modifications in the whales. One of the great whales was the Peterhead Razorback noticed in the previous paper, the other had stranded at Wick in 1869. The Pike whale, showing the deficient parts of the bony transverse processes to be represented by fibrous bands, had stranded at Aberdeen last year. The next specimens exhibited were from the Narwhal, male and female. Possibly in adaptation to the possession of the great tusk, the vertebræ were moveable, while in the female, without the tusk, they were less moveable. The male showed also an additional joint, on the same side as the tusk, between the atlas and axis. Passing next to the stiff-necked whales, Prof. Struthers exhibited a large series of specimens from the Globiocephalus, obtained from the flock which stranded near Edinburgh some years ago. They showed progressive anchylosis of the vertebræ, and degeneration of the transverse processes. The younger ones showed even the rudiments of the epiphyses of the vertebral bodies, on vertebræ themselves rudimentary. The last neck exhibited was that of a Right whale, the interest attaching to which was that, though probably a Greenland Right whale, it presented more of the characters of the Right whale of the South Sea. The conclusion he drew from the study of this neck was that the supposed differences between the Right whale of the North and South Seas were not so fixed characters as had been supposed.

On the Restoration of the Tail in Protopterus annectens. *By* Professor R. H. Traquair, *M.D.*

Professor Traquair described two specimens of *Protopterus annectens*, in which the external configuration and internal structure rendered it evident that a considerable portion of the tail had been broken off, and that in the one case a less, and in the other a greater amount of restoration had taken place. In the first specimen, which measured $8\frac{1}{4}$ inches in length, the body was truncated abruptly $3\frac{5}{8}$ inches behind the origin of the ventral fins. This truncated termination of the body was fringed by a delicate membrane, projecting half an inch backwards in the middle, and containing a pointed central axis. On dissection the abrupt truncation was equally obvious in the internal parts; and the fringing membrane, with its axis, was evidently a commencing restoration of the injured tail, the central axis containing a minute newly formed notochord, lateral muscles, and spinal cord, but there was as yet no new development of neural or hæmal arches, spines, fin-supports, fin-rays, or scales. In the second specimen, which measured $9\frac{3}{4}$ inches in length, and had evidently been truncated or mutilated at a distance of about $7\frac{1}{2}$ inches from the tip of the snout, or $1\frac{2}{3}$ inch from the origin of the ventral fins, the restorative process had proceeded to a much greater length. Although the boundary between the old and new textures was sufficiently indicated on the outside of the fish, by the sudden diminution in the thickness of the specimen and in the size of the scales, the outline of the posterior extremity of the animal was very well restored, though the whole tail was still proportionately shorter than if no mutilation had taken place. The restored portion of the tail measured $2\frac{1}{8}$ inches in length, and on dissection showed not only, as in the former case, a reproduction of the notochord, but also of the neural and hæmal arches, spines, and fin-supports, these elements remaining, however, entirely cartilaginous, and being much more irregularly disposed than in the normal tail. They also cease to be traceable after $1\frac{1}{2}$ inch from the commencement of the new portion of the tail, though the notochord proceeds to its ultimate filiform termination. In addition the spinal cord, the lateral muscles, and the fin-rays and their muscles were in this specimen reproduced as well as the scales on the external surface. Both externally and internally the line of demarcation between the old and new textures was distinctly seen.

On the Morbid Appearances noticed in the Brains of Insane People. *By* Dr. J. Batty Tuke *and* Professor Rutherford.

On the Placentation in the Cetacea. *By* Professor Turner.

The author gave an account of the arrangement and structure of the gravid uterus and fœtal membranes in *Orca gladiator*. The paper is printed *in extenso* in the Transactions of the Royal Society of Edinburgh, 1871.

Notes on the Cervical Vertebræ of Steypirethyr (Balænoptera Sibbaldii). *By* Professor Turner.

The author described in this communication the cervical vertebræ of the large female Steypirethyr whale stranded at Longniddry in November 1869, an account of the soft parts of which he had given in the Transactions of the Royal Society of Edinburgh, 1870. Reference was also made to the cervical vertebræ of a large female Steypirethyr stranded at Northmaven, Shetland, in October of the same year, many of the bones of which are in the author's possession. The following are some of the principal measurements of three vertebræ of the Longniddry Steypirethyr:—

	Atlas. inches.	Axis. inches.	6th C. V. inches.
Between tips of transverse processes	37	$43\frac{1}{2}$	45
Transverse diameter of anterior articular surface..........................	16	18	$14\frac{1}{4}$
Vertical diameter of neural canal	9	$6\frac{1}{2}$	$5\frac{3}{8}$
Transverse diameter of foramen at root of transverse process	0	$8\frac{1}{2}$	$11\frac{1}{2}$

The transverse process of the atlas was not perforated by a foramen; those of the 2nd, 3rd, 4th, 5th, and 6th each possessed a large oval foramen at the root. The 7th cervical vertebra had only its superior transverse process well developed; the inferior was marked simply by a slight ridge on the body of the bone. In the Northmaven specimen the inferior transverse process of the 6th vertebra was only partially developed, so that it did not join the superior, and the boundaries of the ring were imperfectly formed. The author believed that Steypirethyr was not an uncommon whale on the Scottish coasts. In addition to the two specimens already referred to as stranded in 1869, he had also identified the great whale stranded at North Berwick in October 1831, dissected by Dr. Robert Knox, and the skeleton of which is suspended in the Museum of Science and Art, with this species. Belonging also to this species was a whale stranded at Aberdour in July 1858, which he had been able to identify from the nasal bones, which had been preserved by Dr. McBain. Steypirethyr is apparently the largest of the Fin-whales, and it seems to be very doubtful whether the common Razor-back, *B. musculus*, ever attains the length of 70 feet.

Contributions to the Anatomy of the Thoracic Viscera of the Elephant. *By* Dr. M. Watson.

Anthropology.

Address to the Department of Anthropology. *By* Professor Turner.

As this is the first time in Scotland that an Anthropological Department has been constituted in connexion with a Meeting of the British Association, and, indeed, as it is only the third time that a department of the biological section has been formed with this title since the first one, which was instituted at the Meeting in Not-

tingham in 1866, it may not be out of place to say a few words on the object to be fulfilled by this department, on the place which it occupies as a subdivision of the Biological Section, and on the part which it may play in the proceedings of a body like the British Association for the Advancement of Science. First, what signification is attached by men of science in these days to this term Anthropology? The distinguished traveller and naturalist, Mr. A. R. Wallace, who was the first occupant of the chair which I have now the honour to fill, in his introductory address to the Department at the Nottingham Meeting, defined anthropology as "the science which contemplates man under all his varied aspects (as an animal and as a moral and intellectual being), in his relations to lower organisms, to his fellow-men, and to the universe." It is obvious that a science thus defined is most comprehensive in its scope, that it embraces the nature and constitution of man, physically, psychically, and morally; the differences and resemblances between man and other organisms; his habits and language; his history, past, present, and future.

But, we may ask, has the term anthropology always had so wide and comprehensive a meaning as many men of science now attach to it? A brief glance at the history of the term will show us that this has by no means been the case, and that the term has had a variable and progressive signification. With it, therefore, as with so many other terms employed in science and philosophy, it will be needful to ascertain to what school of thought a writer belonged before we can feel assured of the exact signification he attached to it. So far as I have been able to ascertain, the term, under the form of *anthropologos*, first appeared in literature in the Ethics of Aristotle. It occurs in a passage where Aristotle is drawing a picture of a lofty-minded man—"One who will not compete for the common objects of ambition, who will only attempt great and important matters—who will live for his friend alone, will bear no malice, will be no gossip (*ouk anthropologos*), will not be anxious about trifles, and will care more to possess that which is fine than that which is productive." (Grant's 'Aristotle,' 2nd ed. vol. ii. p. 77.) In this passage, Aristotle, who had in all probability coined the term for the particular occasion, employs it in the sense of a talker about himself and others—a mere gossip. With him it had a purely personal signification, and was used to express a single phase in the character of an individual man, and not as a term applicable to mankind in general. We have no knowledge, indeed, that the "science of man" had any place assigned to it in the philosophical systems either of Aristotle or any other Greek philosopher. For though Aristotle himself, in a higher degree than any of his compatriots, had taken a far-sweeping survey of science and philosophy, and had acquired an accuracy of conception of man's moral and psychical characteristics such as may fairly be put on a par with the results of modern investigation, yet his knowledge of man's physical nature was crude and inexact. It is undoubtedly true that he both observed, and recorded observations, on various points in human and comparative anatomy and physiology, but these observations, owing to the imperfection of the method pursued, were wanting in precision. Hence, not only with Aristotle and his contemporaries, but so long as the Aristotelian method of inquiry held firm sway over the minds of men, an inexactness and want of precision in observation prevailed, which rendered it impossible to found a true science of anthropology. Nothing, indeed, is more remarkable in the contrast between the ancients and moderns than the comparative weakness of the former in the sciences based on observation, experiment, and collected facts; and in consequence of the greater superiority of the latter in these methods of inquiry, a division and subdivision of the sciences has taken place in modern times, such as would not have been even dreamed of by the ancient Greeks.

Early in the sixteenth century, when men began to emancipate themselves from the influence so long exercised by the school of Aristotle, the term appeared again in literature under the form *Anthropologeion*, a purely anatomical work bearing that title having been published in 1501 (Bendyshe's 'History of Anthropology,' p. 352); and so late as the year 1784, Professor J. W. Baumer published at Frankfort a treatise on human anatomy and physiology, with the title of "Anthropologia Anatomico-Physica." By these writers, therefore, the word anthropology was limited to the physical aspect only of man's nature. By another school of thinkers and writers the term was employed to express, not the physical, but the moral and psychical aspects

of human nature, and by some divines it was used in a very special sense "to denote that manner of expression by which the inspired writers attribute human parts and passions to God" (Encyc. Britannica). Gradually, therefore, the term has acquired a wider and wider application, until in these days it has been made to embrace the whole science of human nature.

Both in this country and on the Continent societies have been established for the cultivation of this science in its widest and most comprehensive signification, and some of the results of their labours have been given to the world in numerous published memoirs on the anatomy, psychology, languages, arts, and customs of mankind, and on the distribution and characteristics of the various tribes or varieties of men which inhabit or have inhabited our earth.

We may now inquire what place would be occupied by a subject embracing so wide a range of topics as anthropology in the programme of a scientific body organized on the basis of this Association—of a body which, it must be remembered, was originated, and had pursued a highly successful career, many years before men began to think or speak of a science of anthropology in the sense in which the term is now employed. And, without doubt, the first and most logical step was to pursue the course which the General Committee took at the Birmingham Meeting in 1865, to enlarge the scope of Section D, and by altering its title from Zoology and Botany to Biology, to make it embrace the whole science of organization. Anthropology, therefore, or the science of man, naturally came to be included within this Section, and leave was given to the Committee of the Section to form a special department for the consideration of anthropological papers, should memoirs sufficient in number and importance be presented for perusal. So far, then, as the associating of men together in one section can form a bond of union, all those who work at the elucidation of the facts and laws of organization, whether they appertain to the lowliest plant or animal, or to man himself, find in this Biological Section a common meeting-ground. And, I would venture to submit, it is right that it should be so. For the investigation of the physical aspects of man's nature, which necessarily forms so large a part of our proceedings, demands the same precise method of work, and needs exactly the same training, as has to be gone through by all who aspire to excel either in this or in the other departments of biology. If we look at the history of our subject, and, without referring to living men, recall the names of those who have contributed largely to its progress—Haller, Linnæus, Blumenbach, Cuvier, Johannes Müller, William Lawrence, and John Goodsir at once stand out prominently, not only as accomplished anthropologists, but as men well versed in a wide range of biological study. Those who are conversant with anthropological literature will, I doubt not, have little difficulty in calling to remembrance various writings in which errors, not only in the description of objects, but in the general conclusions arrived at from their examination, would have been avoided, if the previous training of the authors had been of a wider nature; if they had fully appreciated the import of the processes of growth and development, nay, even the aberrations from the normal state through pathological changes occurring during embryo, or adult life, to which man is subject in common with other vertebrates.

It is, I trust, needless for me to enlarge further on this topic, so that we may next proceed to inquire briefly into the part which an anthropological department may play in the proceedings of the British Association. In societies devoted solely to the consideration of anthropological questions, and acting as independent bodies, such as the Anthropological Institute of London, or the corresponding Society in Paris, all the subjects included within and constituting the Science of man naturally fall within the scope of inquiry, and come under discussion as opportunity offers. But in this department of the Association we have not that complete independence of action which these societies possess. We are only members of a still larger body, and the function which we perform must be duly subordinated to the common good; and owing to our recent introduction into the programme of its proceedings, much of the ground which many would consider we were fairly entitled to cover, has been largely preoccupied by other and older departments. As the physical aspects of our subject are based on anatomy and physiology, many of the papers on the structure and function of the human body and its constituent

parts may doubtless be claimed by the Department of Anatomy. To other papers, in which comparisons are instituted between human and animal structure, the Zoologists may consider they have a title. To some extent also the habits of man and numerous important questions of a social nature are discussed in the Section of Economic Science and Statistics. The time when man first appeared on the face of the earth, the formations in which his remains and those of contemporary animals are found, may come under the consideration of the Geologists. As our subjects therefore dovetail so intimately with these other Sections of the Association, questions may occasionally arise whether papers submitted for perusal come more appropriately within their province or within ours. Probably the most satisfactory mode of solving this difficulty would be for the different Sections concerned to come to a common understanding that all papers which treat of the origin, varieties, and progress of mankind should be forwarded to this department.

Again, if a separate Ethnological Department or subsection were formed, as has been suggested, or even if ethnological papers were read, as was for so many years the case in the Geographical Section, not only would all these communications on the characteristics of the different varieties of man, or their distribution over the globe, but even papers on comparative philology, and on questions appertaining to the early history of man, and to his primitive culture, in all probability be subtracted from our proceeding. Without doubt, all ethnic questions form an integral part of anthropological study, for ethnology is one of those subjects which form the groundwork of our science; and as it is an axiom that the whole is greater than and includes the part, all these questions naturally fall to be discussed in this department, and should not be divorced from their natural allies. The decision of the General Committee that the ethnological papers should be transmitted to this department was but to restore them to the place they originally occupied in the proceedings of the Association, for in its early years ethnology was a subdivision of Section D. The brief history of this department teaches us that its struggle for existence has been a severe one. It was only after the dissociation of the ethnological papers from the Geographical Section that our proceedings acquired much vitality, and to remove them from us now would be a severe blow to our usefulness.

After recommending the Antiquarian Museum to the attention of visitors, Professor Turner concluded as follows:—As the "noblest study of mankind is man," the subjects which come within the scope of our inquiries in this department are amongst the most important in which a body of scientific men can be engaged. Let us approach their consideration with a spirit of due humility and reverence; let our discussions be so regulated that our desire may be, not to attain merely a personal victory in argument, but, if possible, to get at the truth. And if we claim to be called anthropologists, let not men say of us that our right to be so regarded is rather owing to our proficiencies, in the old Aristotelian meaning of the term, as discussors of persons—mere gossips—than to our qualifications as patient and humble students of the great science of human nature.

On the Anthropology of the Merse. *By* JOHN BEDDOE, *M.D. &c.*

The Merse is the low country of Berwickshire. Its ethnological history is pretty nearly that of the county of Northumberland, with certain variations, which have introduced a little more of the Gaelic and Scandinavian elements. The people are stalwart and bulky in a remarkable degree; a number of the pure breed averaged 5 feet $11\frac{1}{4}$ inches with shoes, and 199 lbs. with clothes. Their heads are large and well developed. The prevailing physical types may be referred to the Anglian and Scandinavian. The hair and eyes are generally light. The fishermen of Eyemouth are a separate breed; they also are very fair, and resemble Dutchmen or Norwegians. Changes in the food of the peasantry (who are giving up oatmeal and milk) and intermixture of blood, may have an unfavourable influence on the physical development of the next generation.

On Degeneration of Race in Britain. By JOHN BEDDOE, *M.D.*

While he allowed that in some classes, and particularly in the upper classes of townspeople, the conditions of life were on the whole improving, and that the operation of the Factory Acts had checked the progress of physical degeneration among manufacturing operatives, the author was of opinion that, on the whole, the agencies tending to promote degeneration were more powerful than the countervailing ones. Among them were the great increase of town population, the relative or even absolute diminution of the inhabitants of rural districts, the increased demand for female and youthful labour, and for labour of a nocturnal or otherwise exhausting kind. He did not think the food of the people improved proportionately with the rise of wages. The disuse of milk among the poor of large towns and some dairy districts was a great evil, and might have to do with the growing deterioration of teeth. England, the richest and most advanced of the four British countries, had been shown by Edward Smith to be the worst fed, so far as regarded the working classes.

Dr. Beddoe's opinions were based in great measure on the results of certain weighings and measurements executed by his correspondents in various parts of the country, and he was anxious to add to the number of these correspondents, and to obtain more data of a similar kind.

On Le Sette Communi, a German Colony in the neighbourhood of Vicenza. By Dr. CHARNOCK, *F.S.A.*

After referring to theories as to the origin of Le Sette Communi, the author of the paper showed that they settled in Italy temp. Theodoric, king of the Ostrogoths. The population amounts to 25,500. The people are principally engaged in breeding cattle. At the present day quite two thirds of them would seem to be neither of German nor of mixed origin, but are pure Italians, and speak Italian. Even the rest of the people (many of whom have intermarried with Italians) bear a greater resemblance to the latter than to the Germans. Dr. Charnock nevertheless noticed many people with fair hair and German features. This was especially the case among the women. The people are simple in their manners, and honest, but are poor, dirty, ignorant, and superstitious. No cases of goitre or cretinism, and no peculiarity of dress were observed. The dialect resembles the Oberdeutsch of the 15th century, and the language still spoken by the mountain-dwellers of the Schlier and Tegern. The author made some remarks on the grammar, and the paper concluded with a vocabulary of some of the most important words, and a specimen of the Lord's Prayer, which Dr. Charnock compared with that of Le Tredici Communi.

On the Physical, Mental, and Philological Characteristics of the Wallons. By Dr. CHARNOCK, *F.S.A.*, *and* Dr. CARTER BLAKE.

The ordinary Wallons stand in the same relation to Belgium as the Irish peasants do to the "Sassenach" of England. They are usually jovial, good-natured, generous, hospitable, chaste, poor, quarrelsome, and superstitious, like the Irish; and thus evince their Keltic descent. They are tough, rough, and hardy, and make excellent soldiers. The Spanish armies in the Pays-Bas were made up of Wallons. As evidence of their peculiar character, a Wallon will drag a pig from Namur to Ghent, Bruges, or Antwerp, to gain a few sous more than he could in his own district. The character of the people differs somewhat in each district. Those of Liège are very lively, spiritual, and laborious; those of Namur proud and coarse. The Wallons of Lower Pomerania stand even lower than those of Namur. Among the Wallons of Liège, even the women are renowned for their strength, industry, and energy. Like the men, they do the hardest kind of work, as coal-drawing, and towing the Meuse boats; and the Germans style Liège "*Hölle der Frauen.*" The Wallon dialect is rich in metaphors, witty in expression, boldly figurative, and full of onomatopœias. Generally speaking, it may be said that the Wallon is a spoken, not a written language. The pronunciation differs in different localities; and such are the modifications of accentuation, that almost every village has its own

manner of expression. Measurements of [illegible] Wallon skulls showed that a greater amount of dolichocephaly was attained in them than amongst any other Keltic race, except the Kerry Irish.

On an Inscribed Stone at Newhaggard, in the County of Meath. *By* EUGENE A. CONWELL, *LL.D., M.R.I.A.*

The author stated that the stone, of which a rough drawing of the natural size was exhibited, lies in a field near the river Boyne, belonging to J. Youell, Esq. The stone is a block of Old Red Sandstone, 2 ft. 11 in. × 2 ft. 10 in. × 1 ft. 8 in. It is known in the neighbourhood by the name of "the Giant's finger-stone." It is now 115 yards from a circular earthen encampment, which the author described.

There are characters on all of its surfaces which the author believes to be cut, and not punched. The author is not able to give any interpretation of these markings.

On the Origin of the Domestic Animals of Europe. *By* W. BOYD DAWKINS, *M.A., F.R.S., F.G.S.*

None of them date so far back as the Quaternary age. The sheep, goat, small-horned ox (*Bos longifrons*), the domestic horse, the dog, the tamed wild boar, and the turf-hog, to which all the European swine can be traced, appeared in Europe at the same time in the Neolithic age. He argued that they were probably derived from the East, and imported by a pastoral people from the central plateau of Asia. The evidence afforded on the point by the southern forms of vegetation found along with this group of animals in the Swiss lakes adds considerable weight to this view. In Britain, down to the time of the English invasion, there was no evidence of any larger breed of oxen than the small short-horned *Bos longifrons*; the larger breed of the *Urus* type were probably imported by the English, and is represented in the present day in its purity by the white-bodied, red-eared Chillingham ox. In the course of the discussion Dr. Sclater fully agreed with the views of the speaker as to the eastern origin of our domestic animals, since the East is the only region in which the wild ancestors of the domestic breeds are now found.

On the attempted Classification of the Palæolithic Age by means of the Mammalia. *By* W. BOYD DAWKINS, *M.A., F.R.S., F.G.S.*

The late eminent French naturalist, M. Lartet, acting on an *à priori* consideration, has attempted to divide up the Palæolithic age into four distinct periods. "L'age du grand ours des cavernes, l'age de l'éléphant et du rhinocéros, l'age du renne, et l'age de l'aurochs." The very simplicity of this system has made it popular. There are, however, two fatal objections to this mode of classification. In the first place, nobody could expect to find the whole Quaternary fauna buried in one spot. One animal could not fail to be better represented in one locality than another, and therefore the contents of the cave- and river-deposits must always have been different. The den of a hyæna could hardly be expected to afford precisely the same animals as a cave which had been filled with bones by the action of water. It therefore follows that the very diversity which M. Lartet insists upon as representing different periods of time, must necessarily have been the result of different animals occupying the same area at the same time. In the second place, M. Lartet has not advanced a shadow of proof as to which of these animals was the first to arrive in Europe. From the fact that the glacial period was colder than the quaternary, it is probable that the arctic mammalia, the mammoth, woolly rhinoceros, and the reindeer arrived here before the advent of the cave-bear. It is undoubtedly true that they died out one by one, and it is very probable that they also came in gradually. The fossil remains from the English caves and river-deposits, as, for instance, those of Kent's Hole or Bedford, prove only that the animals inhabited Britain at the same time, and do not in the least degree warrant any speculation as to which animal came here first. Nor does it apply to France or Belgium,

for in the reindeer-caves of both these countries the four animals in question occur together—the mammoth with the reindeer, and the aurochs with the cave-bear. In Belgium, indeed, the reindeer was probably living in the Neolithic, Bronze, and Iron ages, since it lived in the Hercynian forest in the days of Julius Cæsar.

A Gleam of the Saxon in the Weald. *By* WALTER DENDY.

On the Relative Ages of the Flint- and Stone-Implement Periods in England. *By* J. W. FLOWER, *F.G.S.*

In this paper, the author, after pointing out the great importance of the subject in relation to anthropology, stated that he proposed to show that, having regard to the result of recent researches and observations, the arrangement hitherto usually adopted of dividing the stone age into two epochs or periods only (Palæolithic and Neolithic) was insufficient, as regards England, and that for the purpose of scientific investigation, that which has been called the Palæolithic, might properly be subdivided into at least three distinct periods. That upon geological grounds, the Drift-implement period must be regarded as remote by a vast interval from the Bone-cave period, with which it has been classed by Sir Charles Lyell and Sir John Lubbock, inasmuch as the gravels and sands which now overlie the implement-bearing gravels must certainly have been deposited *after* the implements were formed, and the production of such considerable masses of *detritus* can only have been the work of very extended periods of time, which had been conjectured as embracing even 100,000 years. That since these implements were made, it was obvious that most important geological changes had occurred, and in particular, that during this interval England had been severed from the continent of Europe, as the Isle of Wight had been separated from England. That in England and in France the gravel in, or under which the implements were found, as well as the animal remains found with them, were of precisely the same origin and mineral character, and in both countries resting immediately upon the Chalk; and as further evidence that the implements were made before the separation; and that thus the two countries were then inhabited, may be noticed the fact, that both in the valley of the Somme, and in that of the Little Ouse in Norfolk, the implement-bearing beds are overlain by thick deposits of peat, containing precisely the same vegetable and animal remains, which in both countries are quite distinct from those of the Drift, and of a far later date—amongst others, the Beaver, *Bos longifrons*, Roe, Wild Boar, and Red Deer.

As further evidence of the extreme antiquity of these objects, Mr. Flower also drew attention to the circumstance, that hitherto no implement of the true drift-type had been found north-west of a line drawn from the estuary of the Severn to that of the Wash, between Norfolk and Lincolnshire, following the Lias escarpment, and only a little northward of the limit of the Boulder-clay deposit; and he suggested it as by no means impossible, that when these implements were made, the north of England, and perhaps all Scotland and Wales, were still submerged; and that although the implements were certainly found in Bedfordshire and Norfolk lying on Boulder-clay, those districts, not improbably, were elevated, and perhaps inhabited very long before the lands now lying to the north-west became habitable.

The author considered it extremely improbable that either the drift implements or the gravels in or under which they are found, if transported by river-action, should have been deposited, as had been commonly supposed, by rivers which then ran in the same direction, and drained the same areas as now; inasmuch as they have lately been found at such elevations, and in such situations, as to preclude the belief that at any period since the surface assumed its present contours, any existing rivers could have effected the transport; and in support of this view several recent discoveries were referred to.

He further observed that it seemed by no means certain, as was generally believed, that the makers of the flint implements were contemporary with the elephants and other animals, with whose remains they were often found asso-

ciated; proximity does not of necessity imply (although it may suggest) contemporaneity, at least not in deposits of this character. The animal remains were undoubtedly transported from some distance, together with the gravel in which they are now found, whereas, from various indications which the author specified, it seemed evident that the implements were manufactured from stone taken *from that gravel,* and at that time lying exposed upon the surface.

In order to show that the implements of the Drift were of far greater variety in form and use, and much better workmanship than those of later times, Mr. Flower exhibited a large series, showing sixteen or eighteen distinct forms; and as evidencing the palæontological distinction between the Drift- and the Cave-periods, he stated that while the former contained, so far as at present known with certainty, only six genera and seven species, the latter exhibited fourteen additional species, comprising the important forms of Hyæna, Wolf, Lion, Badger, Elk, and Hare, and thus exhibiting (with one somewhat doubtful exception, that of the Cave-bear) the first appearance of Carnivora amongst the postglacial mammals.

Mr. Flower then adverted to the entire absence from the Drift of any works of art other than the implements, whilst the Caves presented numerous forms of weapons and tools in bone as well as in stone and flint, only one of which could be said to agree with a Drift form; and he added that the Tumulus- or Barrow-period, which he considered was the next distinct Stone-period in order of time in England, was separated from that of the Caves by an interval of vast duration, as indicated by the entire disappearance of the Carnivora and Pachydermata found in the caves, and the introduction, by creation (or as some might say by evolution), of a Fauna almost entirely new, comprising almost all our domestic animals, and in addition the use of bronze, jet, and amber, and other objects indicative of a great advance in civilization.

In conclusion the author expressed his opinion that inasmuch as bronze was certainly in use at the same time with the stone implements of both the Palæolithic and Neolithic types, as evidenced by its presence as well in Celtic tumuli as in the megalithic monuments of presumably later date, it could not properly be regarded as posterior to either of them, or as representing any distinct epoch; and as regarded the Stone-period, he suggested that what had been known as the Palæolithic might properly be classified under *three* heads, viz. *Palæolithic,* to be confined to implements and tools of the Drift; *Archaic* for the Bone-cave objects, and those of like date found on the surface, while the term *Prehistoric* might be used to designate the rude stone flakes and knives &c. found in the barrows; the term *Neolithic* might be applied to all the polished or ground stone implements, while the term *Bronze* might be regarded as common to both that and the *Archaic* period, rather than as representing any distinct era.

On Centenarian Longevity. By Sir Duncan Gibb., *Bart., M.D.*

His observations had reference to the physical condition of centenarians, which helped to show how they were enabled to reach such a great age. They were derived from a comparison of four genuine examples he had himself seen. These he hoped to raise to six in a few days by a visit to two others near Edinburgh. Of the four, two were males, each 103 years of age, and two females, aged 101 and 102; the last of the four was still alive. Regarding their age there was no doubt; for he had been as careful on that point as any believer in the questionable assertion of Sir George Cornewall Lewis that no one ever reached a hundred years. The author found in all four the functions of breathing and circulation performed with the most complete and perfect integrity, there being an absence even of those changes usually seen as the result of ordinary old age. The chest was well formed and of fairly good capacity; the cartilages of the ribs were not ossified; the voice was good, clear, sonorous, and powerful, though a little cracked and tremulous in two—its power depending upon the capacity of the chest and integrity of the lungs. The heart (the great organ of the circulation) was quite healthy, and free from the chief sources of trouble in old persons—namely, fat or its compounds. This circumstance, although it did not prevent moderate calcification of the blood-

vessels, yet was a conservator of all the tissues of the body, and especially prevented the occurrence of those changes which tend to shorten life. There was an absence of the atheromatous changes commonly observed in old people. This explained the appearance of the countenance in all, and imparted a sort of *silvery expression*, with apparently great toughness of the skin, which the author deemed an essential peculiarity in persons over ninety. All the *special senses* were unimpaired except hearing. The eye was clear in all, the sight excellent, all could read ordinary type without spectacles; there was no arc or ring round the clear part of the eye, as observed in most old people. The sense of smell was good; none smoked, used snuff, nor chewed tobacco. The hearing was somewhat impaired in three; in one of the males it was so acute that he could hear the slightest sound. The *mental faculties* were active in all, the memory good. The general health was capital in all, appetite and digestion good, the latter, indeed, uncommonly strong; all possessed the good, sound teeth they had masticated with when young. From this it was readily understood their digestive powers were capital. Taking, then, the condition of mind and body presented by the four undoubted centenarians, it may be said that in all there was an absence of those changes usually observed in persons approaching the allotted period of threescore and ten. These changes have reference chiefly to the condition of the blood-vessels and other tissues which are so seldom found absent. Suffice it to say that complete composure of mind throughout life has had much to do with the condition of body permitting the attainment of such great longevity; there was no hereditary condition also to interfere with nature's laws under such circumstances. Climate does not seem to interfere with longevity, for centenarians are said to be numerous in Russia. To reach that age not only must the constitution be naturally a good and healthy one, but all the great functions of life must be performed without any impediment. If the special senses are coordinately good, they assist in keeping up the condition favourable to longevity. But there is one change antagonistic to extreme longevity, and it is the most important one—namely, the predominance of the atheromatous element which leads to those changes, in the blood-vessels especially, which close life at the natural period. Simplicity of regimen and avoidance of those elements of food which in their assimilation help to bring on those changes may ward it off altogether, although the author was not able to make out whether the four centenarians he spoke of had been in any way particular on this point. In conclusion, he said he believed all centenarians were tired of life, however extraordinary it might appear, and were thankful when it pleased God to remove them from this world.

A Note on the Fat Woman exhibiting in London. *By* Sir Duncan Gibb, *Bart., M.D.*

As a rule, he said, enormously fat women were rare compared with men. Caroline Heenan, now exhibiting in London, is twenty-two years old, and weighs 40 stone, or 560 lbs.; she is 7 feet round the body, 3 feet 6 inches across the shoulders, and 26 inches round the arm. Differing from most fat people, though the limbs are very large, they are not exclusively composed of fat, a large proportion being due to muscular development, which is confirmed by her history and actual inspection. The chest and abdomen are of course enormous, but not from simple obesity. Her growth and enlargement have been progressive from infancy, and withal she has been able to sustain great muscular exercise that would have fatigued ordinary persons, which is opposed to the view of pure adipose enlargement. At nine months she weighed 70 lbs., at nine years she was 11 stone, and at fourteen years 24 stone. She is handsome and pleasing, face not fat nor greasy, is highly intelligent, and not in any way drowsy. She will in all probability progressively increase as she gets older, and may become the largest and heaviest female who has yet been seen.

The Hereditary Transmission of Endowments and Qualities of different kinds. *By* George Harris, *F.S.A.*

The Comparative Longevity of Animals of different Species and of Man, and the probable Causes which mainly conduce to promote this difference. By GEORGE HARRIS, *F.S.A.*

The Adantean Race of Western Europe. By J. W. JACKSON.

On the Anthropology of Auguste Comte. By J. KAINES, *M.A.I. &c.*

The sources of this paper are to be found in the chapters on "Biology" and "Fetichism" of M. Comte's 'Philosophie Positive' and in the third chapter of the 'Politique Positive.' The paper itself aimed to show that the differences between man and the rest of the animal kingdom were not so great as they are usually represented; nor, in fact, were they so numerous as their resemblances. Treating man as the head of the zoological series, it argued that his dominion over animals was from primitive times, and is now a moral dominion rather than intellectual. Man, he went on to say, was the first of animals—not the last of angels. Zoology knew nothing of angels. What differences existed between man and animals were of degree rather than quality. Both knew want, suffering, and sorrow; both had intellect and moral sense; both were educable by love, both had their likes and dislikes, both had to struggle for existence, both were interested by the same sights. What was new struck both and perplexed both alike. Both exhibited faithfulness, reverence, love, pity, and remorse. There was not wanting evidence that both passed through the same intellectual and moral developments. Seeing, then, that the animals had so much in common, what had led man to separate himself from the animals, to exalt himself above them?—the possession of reason, while the animals had instinct only, some persons might say. But a little reflection would show that man was almost as much a creature of instinct as the other animals. A sound biological philosophy made no difference between man and the other animals; on the contrary, it sought to trace his genesis from inferior organisms. Several species of animals had undoubtedly the speculative faculty, which led to a kind of fetichism. The difference was that man had raised himself out of this limited darkness, which the brutes had not yet, except a few select animals in which a beginning to polytheism might be observed, obtained, no doubt, by association with man. If, for instance, we exhibited a watch to a child or a savage on the one hand, and to a dog and a monkey on the other, there would be no great difference in their way of regarding the new object further than their form of expression. The author went on to complain that hitherto psychology had limited itself to the study of man alone, and even his nature had been regarded only from its intellectual side. The psychology of animals had yet to be studied, and that with a desire only to arrive at truth. In concluding, the author urged that it was only in so far as all external nature was used by man for moral ends that it was rightly used, and that the intellect found its true work in directing his affective nature to moral purposes and relations.

The Lapps. By DR. R. KING.

The Laplander offers himself for our inspection as the only European who in any way represents the Circumpolar tribes. The exact position of the Lapps in classification is still an open question. Professor Agassiz classifies them with the Esquimaux and Samoiedes. Dr. Prichard, relying upon philological evidence (a very unsafe guide when taken alone), maintains that the Lapps are Finns who have acquired Mongolian features from a long residence in Northern Europe, but according to Arthur de Capel Brookes, who passed a winter amongst them, the Laplander and Finn have scarcely a single trait in common. The general physiognomy of the one is totally unlike that of the other; and no one who has ever seen the two could mistake a Finlander for a Laplander. A critical examination of three Laplander crania and two casts, contained in the collection of Dr. Morton, and a comparison of these with a number of Finnic skulls, convince the author

that the Laplander cranium should be regarded as a subtypical form, occupying the transitionary place between the pyramidal type of the true hyperboreans on the one hand, and the globular-headed and square-faced Mongol on the other. The Laplander is certainly of low stature, but he is not a pigmy, as he has been represented. The stature of the Esquimaux averages 5 feet 7 inches. In England the average for the men is 5 feet 6 inches, and in Patagonia 6 feet 2 inches; but we have no real measurement of the Lapps. The Laplander is very lean in flesh, and has not the fat and bulk of the Esquimaux. A thick head, prominent forehead, hollow and blear eyes, short flat nose and wide mouth, characterize the Laplander. The hair is thin, short, and shaggy; the beard straggling, and scarcely covering the chin, in which respect he assimilates with the Esquimaux. The hair of both sexes is black and harsh, the chest broad, and the waist slender. He is swift of foot and very strong; so that a bow which a Norwegian can scarcely half bend he will draw to the full, the arrow reaching to the head. Running races, climbing inaccessible rocks and high trees is the usual exercise. Though nimble and strong, he never walks quite upright, but always stooping, a habit obtained by frequently sitting in his hut on the ground. The Laplander was originally Pagan, full of superstition, and believing in magic and omens, and worshipping their chief deity Jumala in a kind of temple in thick remote woods not built with walls and roof, but only a piece of ground fenced as were the old Roman temples, until the planting of Christianity in the time of Ladulaus Magnus in the year 1277—a Christianity differing, however, from Paganism only in name, until the founding of a school by Gustavus Adolphus in 1631, to which the Laplanders owe their progress in the knowledge and love of the Christian religion, which appears from the many useful and eminent persons bred there. The author described at length their marriage ceremonies. They may be called a moral race. Polygamy and divorce are unknown. It is unlawful to marry too near in blood. The author stated that their families are small, rarely exceeding three. The author then described their mode of bringing up young children from their earliest years. Wexionius is of opinion that the Swedes gave the "Lapp" their name from their wearing skins, but lapper and skin-lapper do not properly signify skins. Nieuren derives their name from their coming into Swedeland every year with rags lapt about them, which is the signification of Lapp in Greek.

According to some authors, the inhabitants do not denominate the country, but the country the inhabitants, as in the name Norwegian and others, strengthened by Olaus Magnus, who calls them Lappomanni, Westmanni, and Sudermanni, in which words manni signifying men, they were called Lappomanni, *i.e.* Men of Lappia. Others say that the name of the country is derived from Lappu, which in the Finnonick language is Furthermost, because it lies in the furthest part of Scandinavia. On this point Lehrberg agrees. Ibre derives it from Lop or Lapp, an old Swedish word for wizard or enchanter.

The domestication of the Reindeer and the use of a drum, which is elaborately engraved with birds, animals, and celestial bodies, and is practised incessantly for the purpose of foretelling events, characterize this people from most of the circumpolar family.

On Megalithic Circles. *By* Lieut.-Col. Forbes Leslie.

This paper is intended in refutation of the theory that all megalithic circles were primarily and exclusively sepulchral; and, on the contrary, to show that the great circular monuments were erected or occupied for religious ceremonies by successive generations of the early races of Britain. Although it is not improbable that these ceremonies were connected with the funeral rites of the dead, whose barrows or cairns, sometimes surrounded by "standing stones," were raised around or within sight of the fane by which they were attracted.

The description of the great methalithic circles of England and Aberdeenshire, were illustrated by diagrams to show the peculiarities of construction which distinguish monuments designed for religious ceremonies from "standing stones" which defined or dignified a place of sepulture.

In proof that the same sites were occupied, and the same megalithic masses

were used by successive races or generations, it was shown, from the *position* of certain hieroglyphic figures of an ancient type on some members of the circles in Aberdeenshire, that they must have been overthrown, and reerected in their present form of megalithic circles.

The arguments in favour of the religious object in the *great* megalithic circles were included under the following seven heads:—

I. They were not places of sepulture, but fanes, temples for heathen worship; for no sepulchral deposits which could rationally be connected with the origin of these monuments, had been found within these circles.

II. Not being sepulchral, a religious object may be inferred from the position of the principal group of monoliths being relative to a particular point of the compass.

III. A peculiar type of sculptures, which are not sepulchral, found on members of these circles.

IV. The vast size of some of the circles and of the masses of stone of which they are formed.

V. Having stone avenues, causeways, or other permanent approaches.

VI. Being selected as places for worship by early Christians; and being often called churches, both in Gaelic and in the lowland Scotch dialect, although no Christian church ever occupied their sites.

VII. In India, *stone circles* and other megalithic monuments were anciently, and *now are* commonly erected as places of worship. This was emphatically asserted, on personal observation and the best authority, not as a doubtful argument, but as an undeniable fact, and that the practice existed not in one only, but in many districts, some of which were mentioned, as well as the authorities.

On Ancient Hieroglyphic Sculptures. *By* Lieut.-Col. Forbes Leslie.

In this paper it is maintained that the hieroglyphics found graven on earth-fast rocks, boulders, and rude monoliths in Scotland, are symbols of religious ideas; the argument being confined to such figures as are graven in rude monoliths where no Christian symbol appears.

These hieroglyphics are referred to two distinct types, the most ancient of which appear to have been the works of a race that was superseded by the Celtic, to whom the later type of sculptures may confidently be assigned.

The ancient type is found in many parts of England and Ireland as well as in Scotland, which would lead to the conclusion that a homogeneous people occupied the three countries. This type of figures is found profusely scattered on rocks where sepulture was impossible, and no connexion with any sepulchral remains has been traced.

The second type of sculptures, although certainly of heathen origin, is evidently of a later age. Many of them have been discovered, none, however, beyond the limits of those districts of Scotland which were occupied by the Celtic tribe of Picts.

In this paper the author, whilst maintaining the religious origin of the figures graven on rude monoliths, combats the theory which would assign their origin to a species of Pictish heraldry, and their use to have been as personal ornaments.

The Origin of the Moral Sense. *By the* Rev. J. McCann, *D.D.*

Is the Stone Age of Lyell and Lubbock as yet at all proven? *By* W. D. Michell.

On Bones and Flints found in the Caves at Mentone and in the adjacent Railway Cutting. *By* M. Moggridge.

The caves of the red rocks, half a mile east of Mentone, are in lofty rocks of Jurassic limestone on the shore of the Mediterranean, and at an average height

of 100 feet above that sea, the rocks themselves attaining an elevation of 260 feet. They have now been repeatedly rifled by the learned or the curious; but when the principal cave was nearly intact, the author made a section of it from the modern or highest floor down to the solid rock. There were five floors formed in the earth by long continued trampling; on each, and near the centre, were marks of fire, around which broken bones and flints were abundant, except upon the lowest, where but few bones occurred and no flints. The bones were those of animals still existing. Few implements were found, but many chips of flint, some cores, and stones used as hammers. Perhaps this cave was used as a place for manufacturing flints, which must have been carried from their native bed, distant about one mile.

There is nothing to evince the action of water; on the contrary, the numerous stones that occur are all angular, derived apparently from the flaking off of portions of the rock,—a slow process, and showing that long periods had elapsed between each of those five occupations, and thus evidencing the great antiquity of the present European fauna.

Whatever that antiquity may have been, we now come to still more ancient times.

Below these caves a slope of about 180 feet descends to the edge of the sea. Through the upper part of this slope, at distances from the caves of from 0 to 10 feet, is a railway-cutting 600 feet long, 54 feet deep, and 60 feet above the sea. The mass removed in making this cutting was composed of angular stones, not waterworn. Loose at the surface, it soon became a more or less mature breccia (specimens were produced), for the most part so hard that it was blasted with gunpowder. In this breccia, and at various depths, some of more than 30 feet, the author has taken out teeth of the Bear (*Ursus spelæus*) and of the Hyæna (*Hyæna spelæa*), while with and below those teeth he found flints worked by man (specimens of teeth and of flints were produced).

Bones and teeth of other animals also occur, for the naming of which the author is indebted to the kindness of Mr. Busk, who says that they are almost identical with those found in the Gibraltar caves.

At the eastern end of the cutting described the railroad passes through a tunnel, emerging close to the sea, and near to what is known as the Roman bridge. Here in sinking for the foundation of a sea-wall, bones and teeth were discovered, but not under such satisfactory conditions as at the western side of the tunnel, since the stones were loose and some of them rounded.

Still following the line of the railway to the east, at half a mile a deep cutting occurs through stiff clay, the result of the washing down of the hill-side. In this, at a depth of 65 feet, the author took out the frontal bone and part of the antlers of a large stag (produced). They were perfect, but in such a state that he could save only the parts.

A few feet off, and on the same horizon, were these teeth of *Ursus spelæus*, marvellously well preserved when we consider the time that must have been required for the accumulation of 65 feet of solid ground; and that not in a hollow or a river's bed, but on the gently sloping side of a hill.

The author suggested that the section of the cave evidences the great antiquity of the present European fauna, while the teeth of the Cave Bear and Hyæna found with worked flints some 30 feet deep in solid breccia, add to the proofs hitherto adduced that those beasts were really contemporary with man.

Note on a Cross traced upon a Hill at Cringletie, near Peebles. *By* J. Wolfe Murray.

On Ancient Modes of Sepulture in the Orkneys. *By* George Petrie.

The author stated that sepulchral mounds are very numerous in the Orkneys. Generally they occupy elevated situations which command a view of the sea, or of a lake, or of both, where the latter was attainable. They stand singly or in groups, or are arranged in a straight line. Occasionally they appear as twin barrows.

They differ greatly in size, and there is also much diversity in their internal arrangements. In some of the barrows (which, with rare exceptions, are of the bowl-shape) human skeletons have been found in kists, either lying extended at full length, or on the right or left side in a flexed posture: in one case the skeleton was in a sitting posture. It is not uncommon to find interments both by inhumation and cremation in the same barrow, and even in the same kist.

Graves or kists unconnected with barrows are not unfrequently met with, but they are only accidentally discovered. If barrows formerly existed over any of them, they have long since disappeared.

Some of the largest barrows contained only a small quantity of fragments of burnt bones, or ashes lying about the centre of the barrow, either on a flat stone, or imbedded in a greasy-looking clay. In others the burnt bones and ashes lay on the natural surface of the soil beneath a small cairn of stones, over which clay had been heaped to complete the mound. A third class contained one or more kists, usually of flagstone set on edge, either wholly undressed, or more or less rudely fitted together. The kists, which average about 2½ feet in length and 1½ foot in width and depth, are found to contain either burnt bones or ashes, or cinerary urns of stone or fire-baked clay, in which the bones or ashes have been deposited. Few stone or bronze weapons are found in the barrows or kists, and personal ornaments are still more rarely met with. The urns are usually very rude.

Two human skeletons were found near Kirkwall in a stone kist underneath a barrow; both were in the flexed posture. One was on its right side with its head close to one end of the kist, and the other lay on its left side at the opposite end. The skull of the first-mentioned skeleton has been described by Dr. J. Barnard Davis as presenting all the characteristic features of the Ancient Briton; the other skull was of a greatly inferior type, more square in outline and remarkably thick. A large kist was discovered in another locality in Orkney, also containing two human skeletons lying similarly to those already described, and presenting the same characteristic differences. In each case the skeleton of lowest type appeared to have been rudely treated and recklessly thrust into the kist, while great care had evidently been taken with the other skeleton found beside it. The whole appearance of the skeletons and their arrangement in the kists suggested the question, Were the squat skeletons with the short thick skulls those of slaves or captives who had been slain and placed beside their masters? and have we in them discovered traces of an aboriginal race of colonists of the Orkneys, akin to the Fins or Esquimaux, whose snow houses the so-called Picts'-houses so closely resemble in form and structure, making due allowance for the difference between the materials employed in their construction?

There is another class of tumuli in Orkney known as "Picts'-houses." They usually resemble the Bowl-barrows externally, but when examined the so-called "Pict's-house" is found to be a mass of building, generally circular at the base, containing in its centre several small chambers or cells surrounding a larger chamber. Each cell is connected by a low short passage with the central chamber, and from the latter a passage extends to the outside of the structure, which is circumscribed by a low wall or facing, generally about 2 feet in height. The walls of each chamber converge till at the top or roof they are only a foot or two apart, and the opening is covered in by flagstones placed across it. Occasionally human skeletons have been found in such buildings; but most archæologists were of opinion that the Picts'-houses were not sepulchral. The opening of Maes-how in Stenness, and especially of a chambered mound in its neighbourhood, showed, however that they had been used as tombs, as Mr. Petrie had supposed. A subsequent discovery of a "Pict's-house" within the ruins of a "Brough," or Round Tower, containing human skeletons along with bones of the Ox, Sheep, &c., and two rude stone implements of peculiar form, afforded still more conclusive evidence of the sepulchral character of the "Picts'-houses," and proved beyond a doubt that, even if originally erected as dwellings, they had subsequently been used as chambered tombs. It would be premature at present, Mr. Petrie observed, to attempt to determine the age of the "Picts'-houses," but the "Broughs," with which they appear to be intimately connected, were undoubtedly existing merely as ruined buildings, and in many instances presenting externally only the appearance of huge barrows, when

the Norsemen invaded the islands in the ninth century. The last class received from the Norsemen the name of "Hoi," or gravemound (now called "Howe"), and the former, in which the structures were still visible, were known as "Bjorgs" ("Broughs"). So far as has yet been ascertained, the discovery of iron implements has been limited to the ruins known as "Broughs," which appear to have been known to, and in some cases occupied by, the Norsemen. The mounds which bear the name of "Howe," and have, when opened, been found to conceal the remains of "Broughs," have yielded only stone, bone, and a few bronze relics. Mr. Petrie referred to one of those mounds near Kirkwall, in which he lately found Roman silver coins of the Emperors Vespasian, Hadrian, and Antoninus Pius.

Details were given of various barrows and kists and of their contents, and the descriptions were illustrated by diagrams.

On an Expedition for the Special Investigation of the Hebrides and West Highlands, in search of Evidences of Ancient Serpent-Worship. By JOHN S. PHENÉ, *F.G.S., F.R.G.S., Member of the British Archæological Association.*

The author commenced by stating that he felt bound to give the grounds for his assertion, made at the last Meeting of the British Association at Liverpool, that he had met with evidences of serpent-mounds and constructions identical with those of Ohio and Wisconsin.

Impressed with the idea that if serpent-worship had been a feature in the early religion of these lands some evidences must still remain, he organized a party for searching such localities in the Hebrides and West Highlands as had not been examined with that object, nor had come under the attention of the theorists for serpent-worship, such as Dr. Stukeley and Sir R. C. Hoare; the party was unbiassed, and former theories strictly avoided. It became purely a matter of survey of existing relics that was undertaken.

The paper was very fully illustrated by diagrams, and the author first drew attention to one representing three outlines of animal forms, two being earthen mounds, taken from the elaborate surveys in Wisconsin by J. A. Lapham, Esq., and the third the stone foundation of a "bo'h" in South Uist, in a work by Capt. F. L. W. Thomas, R.N. Though the purposes and materials were different, the designs clearly demonstrated the fact that the early inhabitants of Britain and America made constructions in the forms of animals. From this he proceeded to the earliest pottery, and by his diagrams showed the great similarity between that of the earliest British and American, from a sepulchral urn in the Ashmolean Museum, Oxford, and one taken from a mound at Racine, on Lake Michigan, by Dr. P. R. Hoy, with a similar specimen obtained from Berigonium, and which was on the table. Instances also of cremative burial, and of whole skeletons in the sitting posture, in both countries, clearly indicated a unity of custom. Having, he thought, established these points, he proceeded to trace the course of serpent-worship from the east; he related some of his own experiences of that worship in India, followed it through Egypt to Greece, pointing out that some of the myths covered its struggles with the more intellectual religion of that country, as the destruction of the Python by Apollo, the strangling of serpents by Hercules, and the relapse of Laocoon and his two sons into the grosser rites, and their consequent punishment. Having traced the spread of this worship and its course westward, he next drew special attention to the construction of earthen mounds and tumuli in America and Britain: he quoted from Messrs. Lapham and Squier's surveys, that natural mounds were adapted artificially to peculiar purposes; at Lapham's Peak three artificial mounds were found, of stone and earth, on the lofty summit; the material had been conveyed by great labour; the hill on which the "Great Serpent Mound" of Mr. Squier is placed had been "cut out, evidently to adapt it to the form desired to be constructed." In the 'Annals of Cambridge' a tumulus in the Gogmagog Hills was formed by layers of different soils, each totally unlike the soil of the neighbourhood, and brought by great labour from remote distances. The Castle Hill at Cambridge is a British tumulus raised on a preexisting natural

elevation. The Eildon Hills have similar artificial adaptations; and the author had himself traced the different soils of the tumulus in the greater Cumbrae, and the hollows whence they were brought. He referred to the artificial *summit* of the Dragon Hill, at Uffington Castle, Berks, and suggested that the White Horse and the sculptured rocks at Ilkley were British delineations. After these evidences of adaptation, he described the serpent, lizard, and alligator mounds of Messrs. Squier and Lapham, which contain oval works towards the head, and evidences of altars and fire within them. He then showed by diagrams several mounds that he identified as corresponding with these, some even in minute details; he referred to examples in Arran, in Monteviot Park, in which latter, towards the south and east of what he considered the site of an altar, he discovered human remains, and finally dwelt on a serpentine mound in Argyleshire several hundred feet long, and about 15 feet high by 30 broad, tapering gradually to the tail, the head being formed by a circular cairn, the centre of which had evidently been occupied by a megalithic structure, which he considered an altar, the large stones of which were lying round the base of the cairn. He could not of course adduce direct evidences of the worship of the serpent, but it had been traced as coexistent with sun-worship in America, where these evidences of the serpent were found; and discovering similar remains in Britain, which retains many indications of sun-worship, and as these two forms of worship went almost hand in hand in other countries, he considered himself justified in concluding that he had found examples of it here also, drawing attention to the variety and beauty of the specimens of early British art on the table to show the care and extent of his explorations.

On some indications of the Manners and Customs of the early Inhabitants of Britain, deduced from the Remains of their towns and villages. By JOHN S. PHENÉ, *F.G.S., F.R.G.S., Member of the British Archæological Association.*

The author drew attention to two prominent points, viz. the universality of the circle, curve, or oval in all the earliest British remains; and the similarity of the physics of the various localities where British towns are still traceable. He selected the widely separated positions of Greaves Ash, in the Cheviot Hills, Standlake, near Oxford, and Tolsford Hill, near Saltwood Castle, Kent; and after showing that the same features existed in each of these, although some of the settlements were formed by excavations and some by erections; after referring for examples to the camps, forts, towns, and individual dwellings,—ornaments, as fibulæ, beads, amulets,—articles of domestic use, as the quern,—and to the cup- and ring-marks on the incised stones of Northumberland, New Grange, Ilkley, and elsewhere, he argued that though divided into clans and tribes, yet that these were originally but divisions of one people, as the idea could not be entertained that at the time of these formations, with many of the tribes separating the people of such remote districts, to say nothing of their frequent hostility, different races should have assimilated so much, more especially with interrupted, or indeed no direct communications. He did not, however, mean that this prejudiced the question of cooccupation by a foreign and immigrating, or even preoccupying race, at that time being distinct and unamalgamated with the mass of the people. Assuming these evidences conclusive, he proceeded to compare the constructions with others at a still wider range, selecting in Britain the extreme points of the Hebrides, Caernarvonshire, and Cornwall, and giving examples in the Alps, in Sicily, and even in the wilderness near Mount Sinai, of similar designs; illustrating his arguments by original drawings made by special permission from articles in the Ashmolean Museum at Oxford, and from those of the Palestine Exploration Fund, &c. Referring to the physical features of the localities he had described in Britain, he pointed out the prevalence of the conical hill towards the east of such settlements, with a flowing stream dividing the one from the other, as in the cases of the Breamish flowing between Greaves Ash and the Ingram and Reaveley Hills, the Thames between Standlake and the Beacon Hill, and the stream between Tolsford Hill and Cæsar's Camp. Where localities had not the desired features, or they were

not sufficiently prominent, art was had recourse to, as in the Castle Hill at Cambridge, Silbury Hill, &c. He considered these, evidences of the custom of worship on the tops of such mountains, from their orientation, and recalled the fact of many mountains still bearing names indicative of Baal- or Sun-worship; that the flowing stream formed a division of sanctification or purity; that each settlement had its hill of worship, and that the modern church-spires of the plains had replaced the aspiring flame which once ascended from the several tribal districts or divisions of our land; and that on or near these places of previous occupancy were founded our oldest cities.

From the juxtaposition of ancient British pottery, where large and small urns were found together, from the lateral perforations of both, distinct from perforations for suspension (an example of which in the possession of Professor Rolleston at Oxford has these perforations less than two inches from the *bottom* of an urn of the larger kind), from the material found in the small urns differing from that in the large, and in one case being a mummified heart-shaped body, he concluded that the preservation of the heart in the small urn was also a custom with these ancient people.

Discovery of Flint Implements in Egypt, at Mount Sinai, at Galgala, and in Joshua's Tomb. By the ABBÉ RICHARD.

On Skulls presenting Sagittal Synostosis. By Professor STRUTHERS.

On Implements found in King Arthur's Cave, near Whitchurch. By the Rev. W. S. SYMONDS, *M.A., F.G.S.*

On Human and Animal Bones and Flints from a Cave at Oban, Argyleshire. By Professor TURNER.

All who are acquainted with the topography of Oban, Argyleshire, will remember that immediately behind the houses, which extend in a long row parallel to the sea-beach, an almost perpendicular wall of rock rises to a considerable height.

At the north end of the bay, near Burn Bank House, the rock rises abruptly from the road to the height of a little more than 40 feet. Ivy, mountain-ash, and black-thorn grew out of the chinks in the upper part of the face of the precipice. A bank of earth sloped from the road, at an angle of about 45°, halfway up the face of the rock. Growing out of this bank were several beach trees, none of which had attained any great size; the diameter of the root of the largest was not more than 18 inches.

In the summer of 1869, workmen in the employ of Mr. John Mackay, of Oban, were engaged in quarrying the north-west face of the rock for building purposes, and after penetrating about 15 feet into the substance of the rock, they opened into the deeper end of a cave filled with earth in which a number of bones were found. On the removal of more of the rock and of the bank of earth from its south-eastern aspect, the cave was more fully exposed, and the position and direction of its original entrance were ascertained.

The rock was a dull purple micaceous sandstone, through which ran thin partings of green sandy shale, and belongs, as my colleague Professor Geikie tells me, to an outlying area of the Old Red Sandstone.

The cave consisted of a chamber and an entrance-passage. The chamber was 11 feet high and the same in depth. The entrance-passage was 4 feet high and 9 feet long, and sloped from the entrance down to the floor of the chamber, which it joined at a decided angle. The mouth of the cave was thus higher than the floor of the chamber. It faced to the south, and about 20 feet in thickness of an embankment of earth had to be removed before the entrance was exposed. The cave was almost filled up with earth, in which were found numerous bones and flints.

The bones had no definite arrangement, but lay in the earth in an irregular manner. The floor of the cave was formed of solid rock, its walls were on much of their surface lined by a white calcareous deposit, 1 to 2 inches in thickness. In the roof of the cave was a fissure, widened out below, but which higher up was so narrow as to admit little more than the blade of a knife. The earth within the cave was moist, and it is probable that water had percolated into the cave through the fissure in the roof, and that the calcareous lining had been deposited from it. For my information respecting this cave I am indebted to Mr. Mackay, though several of the points I have referred to I was able to confirm from a personal examination of the locality made in October last. The bones were transmitted to me by Mr. Mackay, and were as follows:—

The skull and greater part of the skeleton of an adult man. Unfortunately the skull was broken to pieces before it came into my possession, so that it is not possible for me to describe it. I may state, however, that the superciliary ridges were well marked, the lower jaw was powerful, the palatal arch was deep. The teeth were partially worn but not ground flat on the surfaces of the crowns, and they exhibited no decay. The tibia, femur, and humerus possessed some peculiarities in form. A second human skeleton was situated about one yard from the adult. From the characters of the skull and of the dentition, it is obviously that of a youth about eight or nine years of age.

The animal bones were mostly those of mammals, but a few bird's bones were also found. They consisted of the teeth, jaws, and long bones of the roe and red deer. Skulls and other bones of the common dog. Skulls and other bones of foxes. Skulls and other bones of a species of Mustela. The humerus and ulna of an otter. Bones of the limbs of the hare. Skull of an Arvicola. A large number of the long bones of the red deer, which have been split into fragments, in all probability for the ready extraction of the marrow. No human bones were found split in this manner. Fragments of calcined bones. Shells of limpets. Fragments of granite and water-worn pebbles. A number of flint nodules and flint chips and implements. Some of the nodules are partially chipped, as if in process of being converted into implements. The nodules are small, and the implements formed from them are necessarily small also. Is it not possible that the differences in the size of flint implements met with in different localities may be due to the fact that flint nodules vary in size in different places, and that the men of the period had to make their implements of a size such as the materials at their disposal permitted? The most perfect of these implements have sharp edges all round, they are comparatively flattened, and in no instance possessed a length of 3 inches, or a greater thickness than about half an inch.

As flint is by no means a common material in Scotland, I was desirous of obtaining from the most competent authority information on the nearest locality from which they could have been obtained. My colleague, Prof. Geikie, writes me: "A few years ago I found a bed (20 feet thick) of chalk flints underlying the great basalt cliffs of Carsaig, on the south shores of the island of Mull. This is, I believe, the nearest point to Oban from which flint could be brought."

I think that the examination of the various objects found in this cavern leads to the conclusion that it had been used as the habitation of man; for we have not only the remains of man himself, the animals on which he fed, the dog which he, without doubt, employed to aid him in the chase, but the implements which he used, and the raw material out of which those implements were manufactured; further, charred remains, which indicate that he had employed fire to cook his food. The great thickness of the embankment of earth in front of the mouth of the cave leads me to think that it had been closed up by a great landslip of the loose earth from the summit of the cliff. Perhaps the human inhabitants had been buried alive in their cavernous dwelling-place.

It is well known that not only in Scotland, but in various parts of the globe, caves have been used, and, indeed, in some localities are still used, as human habitations. What the exact age of these remains may be it may be difficult to say, but the association of flint implements with the human and animal bones points to a considerable antiquity.

On Man and the Ape. By C. STANILAND WAKE, *Director of the Anthropological Institute.*

In this paper the author referred to the agreement in physical structure of man and the ape, and to the fact that the latter possessed the power of reasoning, with all the faculties necessary for its due exercise. It was shown, however, that it was incorrect to affirm that man has no mental faculty other than what the ape possesses. He has a spiritual insight or power of reflection which enabled him to distinguish qualities and to separate them as objects of thought from the things to which they belong. All language is in some sense the result of such a process, and its exercise by even the most uncivilized peoples is shown in their having words denoting colours. The possession by man of the faculty of insight or reflection is accompanied by a relative physical superiority. The human brain of man is much larger than that of the ape, and he has also a much more refined nervous structure, with a naked skin. The author observed that the size of the brain was the only physical fact absolutely necessary to be accounted for, and this could not be done by the hypothesis of natural selection. Mr. Wallace's reference, on the other hand, to a creative will, really undermines Mr. Darwin's whole hypothesis. After referring to the theories of Mr. Murphy and Haeckel, the author stated that the only way to explain man's origin, consistently with his physical and mental connexion with the ape, is to suppose that nature is an organic whole, and that man is the necessary result of its evolution. While, therefore, man is derived from the ape as supposed by Mr. Darwin, it is under conditions very different from those his hypothesis requires. According to this, the appearance of man on the earth must have been in a certain sense accidental; while, according to the author's view, organic nature could only have been evolved in the direction of man, who is the necessary result of such evolution, and a perfect epitome of nature itself.

On certain Points concerning the Origin and Relations of the Basque Race. By the REV. W. WEBSTER.

GEOGRAPHY.

Address by Colonel HENRY YULE, *C.B., President of the Section.*

YOU are aware that the honourable position which has been assigned to me was originally destined for a gentleman, by labours, knowledge, and reputation throughout the world as a geographer, far otherwise qualified to fill it. His lamented removal, within a very short time of the date fixed for this Meeting, compelled the Council of the Association to make prompt arrangements for the presidency of the Geographical Section. The distinguished soldier and scholar who has recently succeeded to the chair of the Royal Geographical Society was unable to attend; and the officers of the Association thought proper to propose me for the duty. I am quite inexperienced in such office; whatever claim I have to the character of a geographer has been acquired in a limited field, and rather from the literary than the scientific side; a variety of subjects must come before us with which I am quite unfamiliar; and I had for these and other reasons abundant misgivings as to the fitness of the choice. But I did not feel at liberty to decline the duty, especially as it was not the first time that, unsought, it had been proposed to me.

Even among an entire company of strangers, the circumstances of the case, and the short time which they allowed for preparation, would, I felt assured, secure indulgence. When I can count so many countenances of friends around, I feel that it is needless to plead for it.

The first natural duty in circumstances like the present is to pay a tribute, however inadequate, to the memory of the eminent geographer whom we expected to

fill this chair. Deeply do I regret not to be able to speak of him from personal acquaintance, or even from correspondence. I knew him only by his works. And who is there that did not? The long list of those works has been rehearsed in so many of the notices that have honoured his memory, as well as in the address of the Vice-President of the Geographical Society, when presenting the medal which he had won by so many years of faithful labour in the cause of Geography, that I need not now repeat them. Indeed, when contemplating the catalogue of such an amount of work achieved, an amateur geographer like myself stands abashed—but feels at the same time that his own limited experience and desultory studies serve at least to furnish him with some just scale by which to estimate the vast labours involved in the accomplishment of such a life's work as Dr. Keith Johnston's. During that life's work of five-and-forty years, there was little or no call for modifications in the assigned dimensions or outline of the inhabited continents of the world, such as were needed in the corresponding space of years that followed the first voyages of Columbus and Da Gama. But with the exception of that epoch, none in history has produced so much change in the atlas of the world, by the modification and completion of internal spaces that once stood in error or in blank upon our maps. Think of the growth of knowledge of which we should become sensible were we to compare sheet by sheet this late geographer's first National Atlas with the latest editions of the maps of his Royal Atlas! Think of the changes that we should find in the representation of Central America and Interior Africa, in the Arctic and Antarctic Circles, in Australia, in Central and Northern Asia, in Indo-China—nay, to some extent in India itself! I will conclude these remarks by quoting the words used by a friend in writing to me on this subject:—"I obtained, at various times, from Keith Johnston, information, which he was always most ready to give; and I had an opportunity of learning something of the wide range of his researches and correspondence, and of his diligence in the pursuit of materials for his work. He seemed to be imbued with the modesty and caution of a true student of a science which is so constantly presenting corrected views of old knowledge, as well as new facts and new means of investigation; whilst he showed the real delight he had in the labours themselves, no less than in the attainment of the results."

I shall in this Address attempt no general view of the geographical desiderata of the time, and of recent geographical progress in discovery and literature throughout the world. Living habitually far from new books and meetings of societies, I am not sufficient for these things; nor, if I were, could I easily vary from the comprehensive epitome of the year's geography which, but two months ago, was issued, though, as we know with sorrow, not delivered, by him who has been so long the Dean of the Faculty of Geographers in Britain, and whose name is as thoroughly and as respectfully identified throughout the Continent with English geography as once was that of Palmerston with English policy. And since I am naming Sir Roderick Murchison, all, I am sure, will be glad to know that, though his power of bodily movement is seriously impaired, his general health is fair, his intellect and his interest in knowledge are as bright as ever; and as for his memory, I will only say I wish mine were half as good! He has desired me to take occasion to express his deep regret at his inability to be present at this Meeting. It is, he said, one of the most painfully felt disappointments that his illness has occasioned; for he had looked forward with strong interest to taking part once more in a meeting of the Association at the chief city of his native country—with which city, I may remind you, he the other day bound his name and memory by strong and enduring ties, in the foundation of a Chair of Geology in this University.

Instead, then, of attempting a review which in my case would be crude, and therefore both dull and uninstructive, I propose to turn to one particular region of the Old World with which my own studies have sometimes been concerned, and to say something of its characteristics, and of the progress of knowledge, as well as of present questions regarding it.

There are, however, one or two points on which I must first touch lightly. Of Livingstone, all that there is to tell has already been told to the world by Sir Roderick Murchison. We know the task that Livingstone had laid out for himself

in dispersing the darkness that still hangs over some of the greatest features of Central-African hydrography, by determining the ultimate course of the great body of drainage which he has followed northward from 12° south latitude—whether towards the Congo and the Atlantic, or towards Baker's Lake and so to the Nile,—as well as the kindred question of the discharge of Lake Tanganyika; but of his progress in the solution of those questions we know nothing. I can but add that Sir Roderick himself has lost none of his confidence in the accomplishment of the task, and in the return of the great traveller at no distant period. That confidence of his has been so often before justified by the arrival of fresh news of Livingstone, however meagre, that we may well retain strong hope, even if it be not granted to all of us to rise from hope into confidence. We trust, then, that Livingstone will never have a place among the martyrs of geography.

One addition, however, has been made during the past year to that long list, in the name of the undaunted George Hayward, formerly a lieutenant in the 72nd Regiment, who had for some years resolutely devoted himself to geographical discovery. After having proved his powers in a journey to Yarkand and Kashghar, which obtained for him last year one of the medals of the Geographical Society, he had started again, with aid from that Society, to attempt an examination of the famous Plateau of Pamir, hoping to succeed in crossing it, and to descend upon the Russian territory at Samarkand. In the Darkot Pass, above Yassin, he was foully murdered by the emissaries of the chief of that district, Mir Wali by name. Public suspicion in India first turned upon the Maharajah of Kashmir, on whose alleged oppressions Hayward, in a private letter, had made severe remarks, which were rashly published by the editor of a local newspaper. The latest intelligence seems to exonerate the Maharajah and to throw the guilt of complicity rather on the Mahomedan chief of Chitral. If he be the guilty man, it may be difficult to punish him, so inaccessible is his position at present; for, to apply the old saw of the Campbells, "It is a far cry to Chitral." I may observe, however, that some sixteen or seventeen years ago a similar murder took place on the persons of two poor French priests at the other extremity of India, and within the Thibetan boundary on the Upper Brahmapootra, and the apprehension of the criminal must have seemed almost as hopeless as in this case. Yet eventually he fell into the hands of our officers of the province of Asám, and paid the due penalty of his crime.

One book recently issued by the India Office I wish to bring to notice in a very few words. I mean Mr. Markham's 'Memoir on the Indian Surveys.' Of this work, excellent in object and in execution, a pretty full account will be found in Sir R. Murchison's Address; my object is merely to say how encouraging I believe a work like this is likely to prove to those who are employed on such duties as the memoir treats of; for they will see that here are recorded with hearty appreciation, in a book that will be largely read and permanently referred to, the labours, always toilsome, often perilous, often fatal, of a great number of zealous servants of the State, the memory of whose merits would in many cases, but for this book, have been left to decay amid the dust of the India Office. The preparation of such a work shows a spirit which has been too often missing in our administrators, and is honourable, not only to the author, but to the Department which has promoted and authorized its publication.

Within the last few days my attention has been drawn to some maps which have been recently issued by the Forest Department of India, showing the geographical distribution of teak and other valuable woods in that country. I regret to learn that the Forest-management in India is looked upon, by some of those statesmen who are now interesting themselves in Indian details, too much as regards its mere results in revenue. But the conservation, and, if possible, the recovery, of forests of valuable timber is a work which the State alone can touch, and which is of the highest importance, quite apart from immediate returns in revenue. There were, I know, some years ago, and no doubt still are, such forest-tracts, where the only hope of recovery lay in their entire closure; and from these, of course, there could be no revenue. During many years of railway construction in India the waste of valuable timber, an article now comparatively rare and costly in that country, and for which in many of its purposes there is *no* substitute, was lamentable and probably irreparable! The teak timbers that bind the walls of

the palace of the Sassanian kings at Ctesiphon in Babylonia—walls and timber dating alike from the fifth or sixth century of our era—are still undecayed! And yet myriads of logs of this precious material have been used up and buried in the ground as railway-sleepers—a position in which decay was sure to arrive in a very few years—when a very little thought and trouble would have provided an enduring substitute of iron. I believe that had a Forest Department been in earlier existence, much of this misapplication of valuable material might have been avoided, or at least the misapplication would not have been at India's cost. Nor is such waste of resources the only evil that forest-conservancy has to guard against. The unregulated denudation of extensive tracts has a marked influence on the rainfall; and it is one of the duties of a forest-conservancy to see that the sometimes furious demands of the market for timber or fuel do not lead to such general and unregulated denudation.

The geographical field on which, with your permission, I propose to expatiate for a little, is that of India beyond the Ganges; I mean in the largest sense of the expression, and inclusive, at least in some points of view, of the Indian Islands. India, indeed, in old times, was a somewhat vague term, or at least it had always a vague as well as an exacter interpretation. In the latter, it had the same application that we give it now when we speak with precision; it meant that vast semipeninsular region roughly limited by the valleys of the Indus and the Ganges, which embraces many nations and many tongues and many climates, but yet all pervaded by a certain almost intangible character which gives it a kind of unity recognized by all. In its vaguer sense, India meant simply the Far East. The traces of such use still survive in such expressions as the East Indies or the Indian Archipelago. Though this vague and large application of the name probably arose only from the vagueness of knowledge, it coincides roughly with a fact; and that is the extraordinary expansion of Hindoo influence, which can be traced in the vestiges of religion, manners, architecture, language, and nomenclature over nearly all the regions of the East to which the name has been applied. Another name has been applied to the continental part of this region, Indo-China. This, too, expresses the fact that on this area the influence of India and of China have interpenetrated. But the influence of China has, except on the eastern coast, been entirely political, and has not, like that of India, affected manners, art, and religion.

The great elevation that we call the Himalya, after passing beyond the utmost eastern limits of the British province of Asám, is continued in a vast mass of compressed and rugged mountains, of whose lines we have no exact knowledge, but which we know still to reach, at points within the bounds of China Proper, a height of 15,000 feet. In Yunnan these drop into a great plateau, standing at an average height of some 6000 feet above the sea, on which are planted the chief cities of that province, whilst branches of mountain-chains extend far to the south and east, reaching the sea or its vicinity at Cape Negrais, at Martaban, in the south-east of Cochin China, and in Fokien.

Looking at the Map of Central and Southern Asia, we see what a barrier the Himalya forms to the drainage of the plateau of Tibet. The Indus and the Sanpu, having their sources within that plateau, and at a very short distance from each other, flow respectively westward and eastward within this barrier till they reach an extreme distance from one another, of about 26° of longitude, before they turn southward and escape into the plains of India.

But eastward from the exit of the Sanpu, the mountain-barrier is forced, within 3° of longitude, by at least six great rivers, counting in that number the Sanpu or Dihong. These six rivers, the Dihong, the Dibong, the Lohit, the Lu-Kiang or Salwen, the Lantsang or great Camboja river, and the Kinsha or upper stream of the Yangtsé, all derive their origin (I believe the fact is beyond reasonable doubt) from far within the Tibetan plateau.

Another great river, the Irawadi, comes certainly from the vicinity of Tibet; but whether it derives any considerable stream from within that region is a point still undecided. The question excited much controversy some forty-five years ago, when Klaproth made a desperate attempt to prove that the waters of the Sanpu, instead of flowing into Asám, were really the head-waters of the Irawadi. The doctrine was backed on Klaproth's part by much Chinese learning, as well as

by violent perversions of ascertained geography, and obtained great currency both in France and Germany. It is now, I believe, abandoned by every body, with the exception (and the exception seems at first a serious one) of the French missionary priests dwelling nearest to that great burst of rivers. But the fact is, that the elder of these laborious men were taught this doctrine in their youth, and sent out furnished with maps on which this heresy was laid down as positive knowledge. And instead of correcting their maps by the facts that reached them in the country, they seem to have felt bound to bend the facts to this condition of their maps.

But whilst we can reject with confidence the idea of any connexion between the Sanpu and the Irawadi, the uncertainty remains whether the Irawadi does or does not derive its chief source from within the Tibetan plateau. The positive evidence is much perplexed; and though a dissertation on the subject appears in the last Geographical Journal, I do not find that this adds materially to our light on the matter. Doubts are expressed in the same paper whether the rivers Salwen and Mekong come down from much beyond the 27th degree of latitude. But here there is really no room for such doubt. The Mekong has been crossed as a large river by that adventurous traveller, Mr. Cooper, above the line of 29°. He did not see the Salwen, but he was within a few miles of it in the same latitude, and knew it well by report. And the French missionaries, who for many years had an establishment upon its banks above lat. 28°, speak of it as a great river. These facts are in entire accordance with the Maps compiled by D'Anville from the Jesuit surveys, and with the Chinese hydrographies translated in the Jesuit collections. The approximate delineation of these rivers, however, all the way from our Asám frontier to the banks of the Kinsha or Upper Yangtsé, is one of the most interesting problems remaining in this part of Asia, and is connected with that other most interesting practical problem, the opening of direct communication between China and India.

Besides the rivers of which we have been speaking there are others of a high class, such as the rivers of Siam and Tongking, which rise far within the Indo-Chinese region itself. Indeed nowhere, I believe, in the world can so many great rivers be found flowing parallel to the sea within so narrow a span. And we shall see how these rivers and the intervening mountain-ranges have affected the occupation of the country.

And here I would digress for a moment.

We heard yesterday, in the General Committee of this Association, an ardent protest against the Geographical and other Sections for appropriating papers of Ethnological character. I should be far from presuming to maintain, in the face of the importance, interest, and bulk that ethnology has so rapidly assumed of late years, that it should not have a field in the Association as independent as its votaries may desire. But I do protest against the proposition that a Geographical Section should be precluded from entertaining papers that deal with ethnology, or any other subject that the forty volumes of the 'Journal of the Geographical Society' embrace. The fields of the different sciences, even the purest, are not, like the "marks" of our Saxon ancestors, patches cleared in a forest that encompasses each and makes a broad separation between one and another. Their circles intersect; and the branch of knowledge which we call geography is deeply intersected by those of other sciences, or rather is made up of appropriations from other sciences applied to its own purposes. We object to have it partitioned, like Poland, among the adjoining empires. The ethnology of a country is intimately bound up with its geography. We shall not grudge that the ethnologist, in his own Section, should deal with geographical considerations; neither let him grudge that any man who prefers to stand upon the old ways, and deal with the ethnology of any country as a part of its geography, should be allowed to do so.

The nations who inhabit this great region are, as you know well, entirely diverse in race from the genuine Hindu, and all or nearly all belong to the Mongoloid type, and are supposed on fair grounds, not unsupported in some cases by tradition, to have descended from the high tracts of the Transhimalyan countries. Exceptions exist, on the one hand, in some fragmentary Negrito tribes; on the other hand we see it alleged in one of the preliminary notices that have alone yet appeared of

the recent French expedition up the Mekong, that certain Tribes are *Caucasian* in feature. This, however, probably does not merit much stress. The same has often been said of the Karens of Pegu—a case in which apparently partiality misled the judgment; for Sir Arthur Phayre testifies that the Karen national physiognomy is essentially Indo-Chinese like their language—though in every Indo-Chinese tribe, as he notes, and as I have often observed, occur occasional and sometimes remarkable exceptions to the prevailing type.

The occupation of this region has seemed to the most diligent students of the characters and languages of these nations to have occurred in something like the following order.

Dark relics of the earliest human occupation are probably the Negrito races found in fragmentary settlements in the Andaman Islands, perhaps (as there is now strong evidence for believing) in the great Nicobar Island, in the spinal mountains of the Malay peninsula and in the Philippine Islands, not to speak of remoter regions. The singular isolation and dispersion of a race so low in civilization seems almost to suggest the idea that they are the surviving waifs of some submerged continent.

But supposing the other races to have descended from beyond the Himalya, we must assign to the migration of the Malay nations the earliest date. They seem to have left upon the continent as their nearest kinsmen the *Chams* or people of *Champa*, if these were not rather a reflex wave of colonization from the islands. To an early tide of migration southward would seem also to belong:—the *Mōns* or *Talaings*, who occupied the deltas of the Irawadi and the Salwen, the upper part of the Malay peninsula, and probably some part of the valley of the Menam; the *Khmer*, or Kambojans, occupying the lower valley and Delta of the Mekong, and flowing over into the Siam basin like the Mōns from the other side; and the *Anam*, or people of Tongking and Cochin China. To these may have succeeded the great family of the *Lau*, *Thai* or *Shans*, who first occupied the plateau and high valleys of Yunnan, the middle basin of the Mekong, and the upper part of the Siam basin. In later days this race has flowed back upon the Upper Irawadi and the Brahmaputra, and has spread south to the coasts of Siam and the Malay peninsula.

The *Karens*, and perhaps some others of the larger hill-tribes allied to them on the borders of the Irawadi, probably followed. Then we have the Maramá or Burman race, apparently descending the Irawadi, pressing before them the Mōns into the Delta, the Khyens and like tribes into the bordering mountains. One great branch of the Burmans, by themselves reckoned the elder, passes over the mountains to the shores of the Bay of Bengal, shores which, according to their traditions, they find occupied by *Bilús*, or *Rakkas*—that is, by ogres or cannibal monsters, from whom in after days the country got its name of Rakhain or Aracan, the country of the ogres.

As usual, the course of civilization, like that of occupation, has mainly followed that of the great rivers, those highways of the primeval world; and their valleys and deltas have been the seat of the more civilized monarchies.

Of these nations that we shall call civilized, then, we have the Burmese still occupying the valley of the Irawadi and the coast-plains and valleys of Aracan; with the exception of those whom we have made the Queen's subjects, they are still all united under one monarchy. The Anamites occupy the eastern shores, and are also now so united, except such as have become subjects of France. Between these two is found the great Shan race, whose settlements are diffused from the banks of the Brahmaputra to the Malay coasts and the delta of the Mekong, divided under an infinity of petty princes and tributary to a variety of sovereign governments, parted sometimes widely from one another by populations of alien blood, but everywhere displaying a fair amount of civilization, everywhere possessing letters and the Buddhist religion, and everywhere speaking substantially the same language—circumstances that seem to corroborate what the traditions of the race assert, both in Siam and in the remote interior, that they are the fragments of some great community shattered and dispersed. Some fatal want of coherence has split the race into a great number of unconnected principalities, many of which are incorporated in the Chinese province of Yunnan, and others tributary to Burma or to Siam. The latter monarchy (Siam) is now apparently the only independent Shan state of any importance in existence. A portion of the race are found in what is now our own

province of Asám, which they first entered in the thirteenth century as conquerors. The *Mōn* or Talaings of Pegu, the *Khmer* of Kamboja, the *Cham* of Champa have also been famous in their days; but they are now shrunken and decayed, and seem likely to be absorbed by the races of greater vitality that encompass them.

These chief races have played the historic part on the field of Indo-China, which countries like England, France, Germany, or Spain have played on the continent of Europe; and each in turn has spread its conquests over wide tracts beyond its national frontiers. Champa, Kamboja, Siam, Pegu, Pagán, and probably Yunnan as a Shan state, to say nothing of the island monarchies, have, with immense vicissitude, in turn been the seats of extensive empires and the subjects of great disasters. But besides these there is a vast mass of races of inferior importance, and generally termed *wild* or *uncivilized*. The fact, however, is that their civilization varies through every degree of the scale except the highest. Many of them are inferior to the so-called civilized races whom they border only in the absence of a written language, whilst others are head hunters in almost the lowest depths of savagery. Some are as elaborate in the cultivation of their rice-terraces as the Chinese themselves; others migrate in the forest from site to site, burning down at each remove new areas on which to carry on their rude hand-husbandry. Nearly all on the frontiers of the States claiming civilization are the victims of kidnappers and international slave-traders.

Among these, so to call them, uncivilized tribes, none are more worthy of note and of interest than those called *Karen*, of whom so great a number have in our own time become Christian under the teaching chiefly of American missionaries. Even before this closer claim upon our interest arose, they were remarkable for the value of their traditions, both religious and what we may call historical. Thus they were distinguished from all other Indo-Chinese tribes by their recognition of the existence of one eternal God. They did not worship him; for, they said, He was angry with them. They believed that their nation had once possessed a holy book, but they had lost it. According to one strange version of the legend, a dog ate it! Their historical legends were almost as remarkable; these related how their ancestors, on their great migration, had to cross the *River of Running Sand*, the name and description of which point apparently to the terrors of the Gobi. They also relate how they found the Shans in occupation of the territory to which they were bound, probably the upper Menam. And the Karens cursed them, saying, "Dwell ye in the dividing of countries," the applicability of which what has already been said about the Shans will interpret.

Speaking generally, the languages of all these races, civilized or wild, are monosyllabic and nasal, with distinctive tones analogous to those of the Chinese, and belong to the same great class with the languages of Thibet and the Himalayan tribes. The written characters employed by the civilized nations, with one exception, are various modifications of Indian writing. The Cochin Chinese seem never to have possessed a similar alphabet, and have no memory of any but the Chinese ideographic character. In the Malay Islands also exists a variety of written characters which it is more difficult to trace to the same Indian root, though they are probably derived from it. If so, they have been carried into wide deviation by modifications, probably springing out of the various implements originally employed, whether the knife-edge upon a bamboo, the graving tool upon stone, the style-point upon the palm-leaf, the steatite pencil upon blackened paper, or black pigments upon slips of wood or ivory.

It is not a little remarkable that, whilst in India Proper there has come down to us scarcely more than one genuine ancient historical record, all the states of Indo-China, even the petty ones of Interior Laos, have from early times preserved chronicles of their respective dynasties. How far these go back with any claim to truth, I am not prepared to say; but certainly from the twelfth century, or thereabouts, their chronology seems to be genuine and trustworthy; for in various comparisons of such fragments of these annals as have been translated, we find a remarkable agreement both mutually and with the facts recorded in the annals of China, which contain so many notices of the border states.

We spoke some time ago of the remains of Hindu influence which can be traced all over these regions. How and when this influence began, we have no real know-

ledge. The Hindus had elaborate poetry, subtle philosophies, logic, grammar, prosody, mathematics, and astronomy, but, as has already been said, no history. Yet that this influence was flowing out in pulses eastward from an early date, and perhaps long before our era, there can be no question.

Take the island of Java as an example. The people now universally profess Mahomedanism, and Mecca is the quarter to which they are taught to look in prayer. But throughout the island are still found the most abundant traces of intercourse with India, and of the settlement of highly civilized colonies of Hindus. The language, radically quite distinct, is largely engrafted with Sanskrit words; the names of the sacred lands of Hindu tradition are attached to the districts of the island; the legendary poems of the people embody the substance of the great Hindu epics, the Mahábhárat and the Ramayana. The soil of the island is strewn with Hindu idols; the Indian system of village communities stands there with a completeness rarely now to be found on its native soil; the ancient Hindu institution of the Jury of Five was found implanted among the immemorial usages of Java; and numerous architectural remains of great magnificence, adorned some of them with sculptured galleries to which I scarcely know a parallel, show in all their details the presence of Indian art and Indian worship. The art is dead; the worship is dead; and no coherent history relates their migration across the seas. But there are the remains of both, pointing unerringly to their source.

That which is true in this respect of Java is true also in a degree and with variation of Aracan, Pegu, Burma, Siam, Laos, Camboja; it is true, in part, of Sumatra and the Malay peninsula, faintly, and probably with only a reflex origin in Borneo, where temples of Hindu type are said to exist far in the interior. Nay, traces of Hindu language have passed at some uncertain period, but probably through Malays or Javanese, into the languages of the Philippine Islands and of remote Madagascar.

China itself came under the potent influence of Hindu religion in the form of Buddhism. Indian words and the forms of Indian architecture could only exist in China after thorough assimilation to the fantastic style of that peculiar people; but I believe both are to be traced. Sanskrit inscriptions may be seen on monuments of antiquity not far from Peking. Thousands of volumes of Sanskrit works on Buddhistic divinity were carried to China in the early centuries of our era, there earnestly studied and translated into Chinese. For a space of several centuries a succession of devout Chinese pilgrims accomplished, by sea or by land, the long journey westward to India as the Holy Land of their faith, and travelled from shrine to shrine, from spot to spot consecrated by the events in the life of the Hindu Sakya Buddha, just as contemporary pilgrims in Christendom made their journeys by sea and land to the Holy Sites of Palestine, or the Convent of St. Catharine on Sinai.

A distinguished Indian archæologist, a brother officer of mine, has lately published a learned volume on the Ancient Geography of India. And of what does it consist? Almost entirely of an endeavour to track the steps of one of those Chinese pilgrims of the 7th century, and, by the aid of the memoirs that he left behind him, to locate and identify the cities and kingdoms of India at that epoch.

In something, one might fancy, of prophetic strain, and in dim presentiment of our English Empire in India, the great King Alfred sent one of his Thanes, Sighelm of Shireburn, with offerings to the tomb of St. Thomas the Apostle on the surf-beaten shore of Coromandel. Near the same shore stood a magnificent shrine of Buddhist worship, one of the sacred places visited by those pilgrims from Cathay—a shrine whose gorgeous sculptures, rescued from destruction by the zeal of one Scotchman, Sir Walter Elliot, and rescued from oblivion by the skill and learning of another, Mr. Fergusson, now stand in dumb amazement in the court of the India office at Westminster!

The Chinese pilgrim from the far East, and the Saxon envoy from the far West, might easily have met upon those shores. What a subject for an imaginary conversation suggests itself!

Buddhism undoubtedly, with its spirit of propagandism, was a most powerful agent in the development of Indian influence among the Indo-Chinese nations; but probably that influence had been felt at a still earlier date. Among the names of towns and islands on the coasts and seas of the further East, as given by Ptolemy,

several are almost certainly of Hindu origin; one at least is interpreted by the geographer himself according to its meaning in the Indian language, and the interpretation is correct. Still it is possible that these names were given subsequently to the first Buddhist movements in that direction; for it is recorded that after the third Buddhist synod, held at the city of Pataliputra or Palibothra, now Patna, as early as B.C. 241, missionaries were dispatched to propagate the doctrine in the Suvarna Bhumi, or Golden Land, which is almost certainly Pegu, the *Chryse, Aurea Regio*, or rather, perhaps, *Aurea Chersonesus* of the ancients.

Probably a later and larger wave of migration and propagandism took place not long after the Christian era; for it is remarkable that most of those nations of the further east that have been tinged with Indian civilization, recognize the Indian era of Salivahana, which is coincident with the year 78 of our reckoning. Another indication of movement eastward about this time is, perhaps, the fact that it is soon after this that cloves, if not other peculiar spices of the Eastern Islands, first appear in the markets of the Western World.

Later still, about the 5th and 6th centuries, we recognize in the coincident traditions of the nations a new efflux of influence in the same direction; but this time it comes not from Continental India, but from Ceylon, an island which, though thoroughly Indianized in its religion and manners, has yet some remarkable affinities in the nature of its products, and perhaps also in that of its people, with those of the further east. This last impulse has never entirely worn out; and as the Western world in general has looked to Rome, or the Russian world to Constantinople, rather than to Jerusalem as the immediate seat of ecclesiastical sanctity, so those Indo-Chinese nations look still, in a degree, to Ceylon as the Mother of their Faith.

I have said that, in the countries of which we speak, Indian influence can be largely traced, not only in religion, but in manners, architecture, language, and nomenclature; and indeed the foreign religion necessarily affects all these. Throughout these regions we find, in such matters as the etiquettes of the Blood-Royal, the forms of royal palaces and court ceremonial, an extraordinary identity, and all pointing to ancient Hindu usages; the titles of the monarchs and dignitaries almost universally embrace high-sounding terms of Sanskrit, or rather of Pali, bearing to Sanskrit much the same relation that Italian bears to Latin, that being the dialect in which the Buddhist sacred books were read in Ceylon, and which is still studied as the sacred tongue in Burma, Siam, and Camboja. In Java, by a strange enough chain of circumstances, we find the very title of *Arya*, Noble or Excellent, which has been adopted as the distinctive note of our Indo-germanic races, assumed by every one claiming nobility among a people of kindred and character so diverse from our own.

As regards the nomenclature of these countries, we find Hindu names extending at least as far east as Southern Cochin China, a country long known as *Champa* or *Mahá-champa*, a title now confined to a small corner to which the one predominant race in later times was limited. This Champa was a name borrowed from a famous Indian state upon the Ganges, occupying the modern district of Bhágalpúr. The kingdom of Camboja had its name from a region beyond the Indus; another region in the same quarter, *Gandhára*, the country round Peshawar, lent its name to Yunnán, now a Chinese province, but still so styled in Burmese state-papers; *Ayodhya*, the ancient city of Rama, from which is corrupted our modern Oudh, gave its name to great cities both in Siam and in Java; the holy city of *Mathra* on the Jumna has bestowed its name both on an island dependency of Java and on a town of Upper Burma; *Irawadi*, the great river of Burma, is but another *Airavati*, the river-name which the companions of Alexander in the Panjáb wrote as *Hydraotes*; *Amarapura*, the recent capital of Burma, has a name purely Indian; *Singhapura*, or Singapore, founded by a Javan colony in the middle ages, and refounded in our own century by the ardent spirit of Stamford Raffles, is the same. And so *ad infinitum*.

But it is in the great architectural remains scattered widely over this region that we find the most striking monuments of Indian influence. The original races are none of them addicted to architecture in solid materials, and have long ceased, as a general rule, to use either stone or brick in their own constructions, unless it be

for the ramparts of their cities, for the elevated platforms of their timber palaces, or for the solid domes which form the symbols to which Buddhist worship is directed. Yet in all, or nearly all, these countries we find remains of an elaborate and grandiose architecture devoted to religious purposes. Such are the ancient Javan temples, generally built of hewn stone, and including the extraordinary pyramid of sculptured terraces called Boro Bodor. Temples analogous to those of Java have been found in Sumatra, and in connexion with one of them a Sanskrit inscription as old as the seventh century; in Burma we find them of fine brickwork, in the remains of the great medieval city of Pagán, on the Irawadi river, whose ruins cover many square miles, and still exhibit several grand structures rising to a height of nearly 200 feet; others, also of brick, exist in the dense jungles which cover the remains of Yuthia in Siam. And but lately we have become acquainted with the vast remains of Cambojan architecture—immense temples and corridors of hewn stone, with furlongs of sculptured bas-reliefs. In Champa remains of similar character are alleged to exist; but we have no account of them. Each of these different series of remains has its own peculiar characters; but often there are close resemblances of general design, and in the ornamental detail throughout the whole of the series there is much of this resemblance; and that is of Indian character. Yet it must be said that, of the buildings as wholes, we find no type anywhere in India. Recently I have been much struck by photographs of ancient remains in Ceylon, in the possession of Mr. Fergusson, which afford strong corroboration of a suspicion long ago expressed by myself, that the nearest archetype and common parent of these structures may have been in that island.

Time compels me to omit much that I had noted regarding the progress of our knowledge of these countries, and to hasten down to our own times.

After the mission of Colonel Symes and Dr. Francis Buchanan to Ava in 1795, no material advance was made in our knowledge of these regions till the time of the first Burmese war, in 1824–26. For several years from that time the British Government in India exhibited a zeal for the extension of geographical knowledge such as rarely possesses any Government. A little army of surveyors and explorers were thrown upon the frontier of Asám; and the remote territories lying between Asám and Bengal on the one side, and Northern Burma on the other, were partially explored. Some of our officers traversed Northern Burma from Ava to the frontiers of Asám and Silhet; others, starting from Maulmain, visited most of the Western Shan States from the neighbourhood of Ava to the Siamese capital. And in 1837 Lieutenant (now General) William Macleod, of the Madras Army, accomplished the most important journey that had been made, by penetrating across more than half the breadth of the peninsula to the remote state of Kiang-Hung on the great Camboja river, and close to the frontier of China.

After this the abnormal fire of exploration, which the forced collision with Ava had developed in the Government, seemed utterly to die out.

The credit of kindling it again to some extent has been undoubtedly due to the agitation which certain gentlemen have carried on with amazing persistence for many years, in order to promote the opening of an overland trade with China from Rangoon.

For many centuries a considerable land-trade has been maintained between Western China and the valley of the Irawadi. As long ago as 1459, we find on the great Venetian Map of Fra Mauro a rubric attached to a certain point of the upper waters of the river of Ava—"Here goods are transferred from river to river, and so pass on into Cathay." And as early as the first half of the seventeenth century, there is some evidence that the East-India Company had a factory or agent at Bhamo. Of this trade the staple export from China used to be the silk of Ssechuan, and that from Burma cotton; but many minor articles contributed to its aggregate. The object of the agitation to which I have alluded has been to stimulate the Indian Government to take measures for drawing a similar trade in the produce of Western China to our ports on the Bay of Bengal, and, as necessary for that object, to promote the construction of a railroad from Rangoon to the Chinese frontier beyond the Mekong. Meantime the trade by the old route from Talifu in Yunnan to Bhamo had ceased; and to explain this, a slight digression is needful.

It is a remarkable circumstance that in our own older Indian territory there is no province where Mahomedanism is so extensively professed among the peasantry as the remote and secluded district of Silhet, in the east of Bengal. And China affords a curious parallel; for there is no one of the eighteen provinces of China Proper in which Mahomedanism is so prevalent as in the secluded inland province of Yunnan. And this has been the case from a very early period. Already, in the 13th century, a celebrated Persian historian of the Mongols states, though no doubt with great hyperbole, that in Yunnan all the people were Mahomedans. Since about 1855 this Mussulman population has been in a state of revolt against the Imperial Government; and, after wars which have devastated the greater part of the province and which indeed still continue to do so, a part of the Mahomedans have succeeded in establishing their independence in Western Yunnan, under a sultan of their own election, who bears the name of Suleiman, and reigns at Talifu. The anarchy of civil war and the interruption of communication between the Imperial and the Mahomedan parts of the province, as may easily be imagined, have brought the trade practically to a standstill.

Several expeditions of exploration and survey to the eastward and north-eastward of our province of Pegu resulted from the stimulus of agitation; but the most important of these undertakings was that despatched under Major Sladen, political agent at the Court of the King of Burma, to visit the Mahomedan authorities in Western Yunnan, and to endeavour to bring about a reopening of the trade. Notwithstanding every promise of support on the part of the King of Burma, and of ostensible orders issued in that sense, the expedition was grievously harassed and retarded by most vexatious proceedings on the part of the Burmese provincial officers—a course ascribed by Major Sladen to bad faith and ill-will on the part of the Court itself, but by Sir Arthur Phayre rather to the jealousy of the Chinese merchants, who feared that the trade might revive only to pass out of their hands.

Major Sladen did eventually make his way to Momien, the first city of China met with on passing that frontier; and to him belongs the credit of being the first European to pass that frontier from the side of the Irawadi. He was most cordially received by the Mahomedan Governor; and his visit ascertained that there was perfect good will on the part of the Mahomedan authorities towards the reestablishment of trade. But the causes which had brought it to a stop still existed, and the goodwill of the rulers could do nothing material to restore trade until order and peaceful communication with the interior of China should be reestablished.

A year and a half before the commencement of Major Sladen's journey, another one of a very remarkable character had been undertaken under the orders of the French Imperial Government. This was an expedition for the exploration of the Mekong, or Great Camboja River, starting from the recently acquired French territory in the delta of that river. Before I was called so unexpectedly to occupy this chair, I had commenced the compilation, from the imperfect materials accessible, of an account of this expedition, which I look on as the most important geographical enterprise that has been accomplished in Asia, at least since Burnes's journey to Bokhara. The work of preparation for the duties of the Section prevented me from making any progress with the paper, though I hope on one day of our sitting to give a sketch of the journey. I will only say now that the mission party, consisting mainly of naval officers, ascended the river, first by boat and afterwards by land, to Kiang-Hung, the point reached thirty years before by Macleod. Here they were compelled to abandon the line of the Mekong; but starting to the north-east they entered the Chinese frontier at Ssemao (the Esmok of Macleod), and travelled across Southern Yunnan to the capital city of the province, almost everywhere tolerably well received by the Chinese authorities. A detachment of the party under Lieutenant Garnier succeeded in reaching Talifu; but they had to leave it immediately, at the peril of their lives; and on their return to Tong-chuan, where they had left their chief, Captain De la Grée, seriously ill, they found that his death had occurred a few days before. Taking his remains with them, they proceeded to the Great Kiang at Siuchau, and thence descended to Shanghai, in reaching which they completed a journey of several thousand miles, which had occupied two years.

About the same time Mr. Cooper made his two gallant attempts—first, to reach

India from Ssechuan, and again, with singular perseverance, to reach China from Asám.

The French expedition ascertained that there is no hope of using the Mekong as a commercial route from Yunnan. Though large spaces of its course afford good navigation, this is not only interrupted at no great distance from the head of the delta by actual cataracts, but at intervals by long tracts of rapids, and above the frontier of the Burmese Tributary States the river becomes so rapid as to be continuously quite unfit for navigation. Much the same has been ascertained of the Salwen. Neither of these rivers, therefore, can be turned to account for communication with Western China. The Irawadi remains; and the experience of Major Sladen's ascent to Bhamo, during the month of January, in a steamer navigated entirely by Burmese officers and crew, appears to show that this river is fairly navigable to that station by steamers drawing not more than 4 feet of water.

Many startling and inconsiderate statements appear in the memorials and other documents which have been addressed to Government on the subject of the new routes for trade with China—as, for example, when the agitators of the question talk of thereby opening up a new trade for our country with 200 millions of people, occupying extensive and rich portions of the earth—as if, forsooth, the trade and products of a vast and varied portion of the earth's surface, merely because that portion happens to be described by one name as China, were like the water in a lake, which may all possibly be drained dry if but tapped at a single point in one of its narrow creeks. The moderation and cautious good sense of one of the memorials, however, forms so striking and refreshing a contrast to such statements as I have referred to, that I will quote it almost in full; it is not long:—" Your memorialists have long entertained the opinion that it would be of the utmost importance to the commerce of this country if a route were opened between Rangoon and the interior of Western China. . . . . . The information which your memorialists possess on the district through which the various routes hitherto proposed pass, does not justify them in expressing any decided opinion either with regard to any one of these proposed routes, or as to the practicability of opening any route. But the memorialists would respectfully urge upon Her Majesty's Government the propriety of completing the survey which has already been commenced, with the view of authoritatively establishing whether it is practicable to open up such a line of communication." And I am happy to observe that this dignified and reasonable memorial comes from the commercial metropolis of Scotland; it is the memorial of the Glasgow Chamber of Commerce and Manufactures.

The probability of a great attraction of China trade to the ports of Pegu, even if there were a good highway opened out to the Chinese frontier, depends not on rhetorical statements about the vast population and products of the Celestial Empire, but (and here I will borrow a felicitous expression which I remember to have been applied in India by that admirable public servant the present Governor of Jamaica, Sir John Peter Grant) on the question where the *trade-shed* of that produce shall be found to exist—a question on which I have never seen any great light thrown. As regards the important part of the export trade at least, we have to look not to Yunnan and Kwei-Chau, which are in the main mountainous regions, and comparatively unproductive, but to Ssechuan. I observe that Mr. Cooper, a sensible and on this point quite unprejudiced observer, does consider that a large part of the produce of Ssechuan would seek an outlet by the Irawadi if the land route were again open. Looking to the length of land journey from the fertile portions of Ssechuan to Bhamo, this opinion certainly surprises me. But the fact is that we know extremely little of the extraordinary skill of the Chinese in utilizing rivers which we should in this country regard as mere trout-streams, for internal navigation, or of the extent to which such means apply in reducing the length and cost of the route in question. My own impression is that the Yangtsé, in spite of all the difficulties of its upper reaches, as being free from the complications of a double frontier, and the anarchy of tribes imperfectly controlled, will carry to the sea for many years to come the produce of Ssechuan and Central Yunnan, rather than any outlet by Burma or the Shan States. I do not myself see how the long land-route by Kiang-Hung could become attrac-

tive without a railroad; and the construction of a railroad in such a direction certainly seems to me visionary. Coming to practical questions, who is to pay for such a scheme? The Government of these islands? The question needs no answer. The gentlemen who are so ready to memorialize Government on the subject? If they will, it is well; but I doubt it. If in our own old Indian territory, after railways have been making for twenty years, it has been found impossible to get a single line of railway undertaken except with a guarantee (that is to say, practically, as the guarantees are, at the cost of the Government), is it likely that men who withhold their money there, will risk it in driving a railway through a scantily peopled and almost unknown region to tap a remote corner of China? Is it, then, the Indian Government that is to be at this expense? I remember how a somewhat similar system of agitation induced a former Secretary of State, in opposition to the views of the Indian Government, to sanction the guarantee of a short but costly railway on like speculative grounds—I mean from Calcutta to an uninhabited swamp upon a creek of the Delta, which it was expected would prove a great harbour of commerce; but that line is now almost a pure dead weight upon the Indian revenue. The Indian Government is already sufficiently burdened with railway guarantees, to say nothing of the immense amount of work already laid out, and still to be done, in completing its domestic railway system. When mutterings of discontent on account of increased or changing taxation are beginning to be heard so audibly in India, a wise Government will hold back for a time from measures of almost sure benefit, rather than disregard a warning so ominous. And it would be mad, under such circumstances, to engage its revenues in costly and speculative schemes for the extension of British commerce so problematical as this.

What I think we may reasonably hope for is:—first, to see Western China tranquillized, and the old channel of trade restored and stimulated by the access of British steamers to Bhamo; secondly, from gradual but inevitable political change in our own relations to the Burmese Government, I should expect to see our own influence brought into more direct operation at Bhamo, so that we shall be able to act either in the suppression of marauding, or in opening out by engineering the short road to the Chinese frontier cities, unhampered by such paltry obstacles as the intrigues of Burmese underlings, or the jealousies of Chinese traders. And I venture to think that our Government, as a general rule, need neither grudge the small cost of surveys and explorations beyond our frontier, nor hesitate to apply some degree of pressure on native governments to sanction such measures, without which these governments are apt to think us not in earnest in our proposals. If my memory does not deceive me, our Minister at Peking, in 1860, declined even to apply to the Chinese Regency for passports for an expedition which Lord Canning had sanctioned for exploration in Thibet, and in consequence a promising geographical enterprise was abandoned. The French Minister, in 1866, was less punctilious in pressing a similar demand. The expedition of the Mekong was in consequence furnished with imperial passports; and these passports, even in such a time of civil war and confusion, backed by tact and energy, secured them everywhere in China a decent, and sometimes a cordial reception, as well as free passage through those hitherto untraversed provinces.

On the Principality of Karategin. *By* Major-General ABRAMOF.

On Minicoy Island. *By* Major BASEVI.

The author, who was connected with the Great Trigonometrical Survey of India, visited the island (which is situated west of Cape Comorin) with the object of comparing the intensity of gravity on an island station with that at inland stations in the same latitude. The result of Major Basevi's observations was the conclusion that the force of gravity is greater on the coast than inland, and at an ocean station like Minicoy greater than on the coast. The island is of coral formation,

covered with cocoa-palms, and contains more than 2000 inhabitants, who are of the same race as the Maldives, and of the Mohammedan religion.

On the Ruined Cities of Central America. By Captain L. Brine, *R.N.*

The author stated that it was not until the year 1750 (more than 200 years after the Spanish conquest) that the existence of ruined cities and temples lying hidden in the jungles and forests of Central America was revealed to the knowledge of the Spanish Government. A small party of Spaniards, travelling in the State of Chiapas, happened to diverge from the usual track leading from the southern limit of the Gulf of Mexico to the Mexican Cordilleras, and accidentally discovered in the dense forest remains of stone buildings—palaces and temples—with other evidences of a past and forgotten civilization of a very high order. These ruins were those of Palenque. Some years subsequently to this discovery, the King of Spain ordered an official survey to be made, and this survey was made in 1787 under the direction of Captain del Rio. Later official surveys were also made in 1806 and 1807; but these, with the usual secrecy of the Spanish conquerors, were not generally made public, and thus it happened that only as recently as the year 1822, at the revolution of Mexico, did the existence of these ruins first become known in Europe. Since then other hidden cities or temples had been discovered—Copan, in the State of Honduras; Ocosingo, on the frontiers of Guatemala; and several in Yucatan, of which Uxmal and Chichen-Itza are the most famous. It was very remarkable that all these ruins, evidently the work of one particular and highly civilized race of Indians, should only be found in a very limited area. None exist in South America, and none in that part of the continent commonly distinguished as North America; they all lie within the Tropics, between the 14th and 22nd parallels of north latitude, and were chiefly adjacent to the Mexican and Honduras Gulfs, or in the plains on the west of the Cordilleras of Central America. On the eastern or Pacific slopes and plateaux, within the same parallels, are also remains of ancient fortifications and sacrificial altars, but these are of a less elaborate type, and are allied to the Aztecan structures of Mexico. The author gave an account of a journey made by him across the continent in the spring of last year, from the Pacific, through Guatemala, to the Atlantic; he examined in detail the mixed populations and conditions of the countries between the Cordilleras and the Pacific, the central plateaux, with their aboriginal Indian races and ruins, the region (almost entirely unknown) inhabited by those unbaptized Indians called the Candones, near which lie the ruins of Ocosingo and Palenque; he concluded the journey by traversing Yucatan, visiting the strange ruins with which the country abounds, and emerging on the northern coast of the Peninsula at Sisal.

The Interior of Greenland. By Dr. Robert Brown.

After reviewing the old ideas of the nature of the interior, Dr. Brown spoke at length of the views which his own studies and those of others had led him to. Various more or less successful attempts had been made to penetrate into the interior, viz. by Dalager, Kielssen, Rink, Hayes, Rae, Nordenskjold and Berggren, various Danish officers and Eskimo on hunting trips, &c., and one in which, with his companions MM. E. Whymper, A. P. Tegner, C. E. Olsen, J. Fleischer, and an Eskimo, he had shared in. The result of all these expeditions showed that the interior is one huge *mer de glace*, of which the outlets and overflow are the comparatively small glaciers on the coast, though in reality, compared with the glacier-system of the Alps, they are of gigantic size. The outskirting land is to all intents and purposes merely a circlet of islands of greater or less extent. There are in all probability no mountains in the interior, only a high plateau from which the unbroken ice is shed on either side to the east and west, the greatest slope being towards the west. This "inland ice" was increasing, as necessarily it must, and would most likely eventually overlie the country as it once had in former periods of the earth's history. He considered that Greenland might be crossed

from side to side with dog or other sledges, provided the party started under experienced guidance, and sufficiently early in the year before the snow was melted off the ice. Whether they could return without assistance on the other side was, however, a matter of doubt. No fjords now stretched across within the explored limits of West Greenland. If they did, it was north of Smith's Sound, where perhaps Greenland ended in an archipelago of broken islands. Little doubt existed but that in former times one or more fjords stretched across the country, but these are now permanently closed by the spread of the "inland ice."

Cagayan Sulu Island. By Captain CHIMMO, *R.N.*

On the Second German Arctic Expedition.
By Dr. COPELAND, *Astronomer to the Expedition.*

It stated that the two expeditions sent by the German nation in the year 1868 and 1869 to endeavour to add to the geographical and general scientific knowledge of the Arctic regions were equipped entirely by private contributions, and the honour of starting and forwarding the whole scheme belonged to the eminent geographer Dr. Petermann, of Gotha. The object and aim of the second expedition was the scientific examination and discovery of the Arctic central region contained within the 75th parallel of north latitude, taking the coast of East Greenland as a basis. The aim involved two problems:—(1) The solution of the so-called polar question; (2) the discovery, survey, and examination of East Greenland, and those countries, islands, and seas connected with it, and extending in a northerly direction towards Behring's Straits, a measurement of a meridional arc in East Greenland, excursions on the glaciers of the interior of continental Greenland, &c. The two vessels engaged in the expedition were the 'Germania,' 145 tons, Captain Koldeway, and seventeen men, and the 'Hansa,' 100 tons larger, Captain Hegemann, with a crew of twelve. The expedition sailed from Bremerhaven on the 15th of June, 1869, and after a tedious voyage of five weeks up to the parallel of 75°, the vessels were separated in a dense fog. The 'Germania' reached Sabine Island on the 5th of August, and four days were spent in surveying the neighbouring country, observing an eclipse of the sun on the 7th, determining the magnetic constants, &c. On the 10th they proceeded northwards, but their progress came to a dead stop on the 13th, in latitude 75° 31′, or 23′ further north than had been reached by Clavering and Sabine forty-six years before. At this point the land-ice lay quite fast, and extended fully ten miles in a N.E. direction from the nearest land, since called Cape Börgen; while against its outer edge the enormous fields of pack-ice were so heavily pressed as to render all progress impossible. Towards the N. and N.E. no water was visible; this was just as Captain Clavering and Sir Edward Sabine found matters twenty-three miles further to the south, and within a day of forty-six years before, and it was also their lot to encounter the same obstacles in latitude 75° 29′ in the following summer. Captain Koldeway determined on returning to the Pendulum Islands, and there to await in safety a change in the state of the ice. The remainder of the month of August and the beginning of September was spent in obtaining geological, botanical, and ethnological specimens, and in making various observations. A sledge excursion, under Koldeway and Payer, into a fiord to the N.N.W. of the Pendulum group, from the 13th to the 22nd of September, resulted in a confirmation of a previous supposition of the existence of a large island on that part of the coast, and showed how much might be attempted in the exploration of the interior of Greenland at this season of the year. A second sledge excursion at the end of October and beginning of November was made by Payer and himself round the north of Clavering Island, thereby proving its insularity, which had been suspected by Clavering in 1823. On the 5th of November the sun disappeared for the winter, but still they accomplished about 180 nautical miles in nine days, including the penetration into a new fiord, whose termination they succeeded in reaching. From the 12th of October to the beginning of May, while frozen in, observations were

made as to the temperature and pressure of the atmosphere, the direction and velocity of the wind, the amount of cloud, and the height of the tide from hour to hour. In making these and other observations the scientific members of the expedition were zealously assisted by the two mates, Messrs. Sengstacke and Tramnitz, and the talented seaman Peter Ellinger, whose subsequent death at the early age of 24 has robbed nautical science of one of its most promising supporters. January 1870 was the coldest month, with a mean of 11°·9 Fahr. below zero; and towards the end of February the thermometer reached its lowest, $-40°·5$; but samples of pure mercury did not show any sign of freezing. The mean of the whole year was remarkably low, being only $+11°·3$ Fahrenheit. Magnetical and astronomical observations were made from time to time. The magnetical constants of their winter quarters in lat. 74° 32′ 16″ N., and 18° 49′ W. long. were:—declination, 45° 8′ 8″; inclination, 79° 48′; and horizontal force 0·956 Gauss's scale *. The northern lights were not in general particularly brilliant, but were extremely frequent, and the convergence of the streamers was found to coincide with the direction of the freely suspended magnetic needle. The spectroscopic examination of the auroral light fixed the place of the green line at 1245 of Kirchhoff's scale. The main direction which the labours of the expedition took during the spring was the prosecution of a sledge journey to the north under the leadership of the Captain, who was accompanied by Payer and six seamen. An advance was made of 150 miles in a straight line from his winter quarters, and added at least one whole degree to our maps of the coast of East Greenland. A week afterwards Payer conducted another party towards the fiords to the north-west of the Pendulum Islands, and they succeeded in bringing back a magnificent collection of fossils and minerals. At the same time Dr. Börgen and himself were engaged in the measurement of an arc of the meridian, commenced in the beginning of March, by measuring a base of rather more than 709 metres in length on Sabine Island. On the 14th of May, Dr. Copeland and his companions started on their geodetical tour towards the north, intending to select and signalize their stations as they advanced northwards. All the angles at sixteen out of seventeen selected stations were measured, and the latitude of the north end, as deduced from eighty-two circum-meridian altitudes of the sun, was 75° 11′ 30″·12, with a probable error of 0″·78; that of the south end, 74° 32′ 15″·86, probable error 0′·58. The highest station was 1008·4 metres above the level of the sea. They took advantage of the opportunity thus afforded for comparing altitudes determined with the barometers with those deduced from purely trigonometrical operations. The whole of the barometrical heights were slightly in excess of the trigonometrical ones. Their geodetical labours were very much restricted and embarrassed by the setting in of the thaw as early as the 3rd of June. The ship was freed from her winter prison on the 11th of July, but they did not sail till the 22nd. So far as examined, the botanical and zoological collections had yielded no absolutely new varieties, but had taught much about the distribution of plants and animals. Perhaps the most important discovery in that department was that of the musk ox, which animal was found plentifully up to the 77th parallel. With regard to natives, although the whole coast from the 76th parallel to the innermost recesses of Emperor Francis-Joseph's Fiord, in lat. 73 deg., abounded in vestiges of the aboriginal inhabitants, and although Clavering fell in with a party of twelve on the south side of the island which was now known by his name, this expedition never even met with recent traces of their presence. However, they succeeded in finding eleven skulls, and many interesting weapons and utensils. Being again stopped by the ice in 75° 29′, it was decided in full conclave to try their fortunes in some of the fiords supposed to exist towards the south. They accordingly proceeded southwards along the coast until they rounded Hudson's Hold-with-Hope, and proceeded to explore the interior of the supposed Mackenzie Inlet. A single day, however, served to show

* Note added August 14, 1871.—A letter received from Capt. Koldeway, just after the reading of this paper, enables me to give the following particulars which have been deduced from the tidal observations. At Sabine Island the mean range of the tide was 3·13 ft., range of spring-tides 4·21 ft., that of neap-tides being only 1·86 ft. The tidal wave advanced from the south towards the north at the rate of about 50 to 60 miles an hour.

that no such inlet existed, and thus that what had been called Bennet Island, was only a hilly promontory. Payer and himself afterwards resolved to ascend Cape Franklin, and from its summit saw about sixteen new islands, and upwards of 170 icebergs of from 100 to 200 feet in height. Towards the S.W., at a distance of 60 nautical miles, lay a chain of mountains of 6000 or 7000 feet high—most probably the Werner Mountains of Scoresby. About eleven o'clock they started for the western or higher end of Cape Franklin, whose height they assumed to be 4000 or 4500 feet. There they found that the bay or fiord bent round towards the N.W., sending branches in a westerly direction, while to the north it seemed to expand into magnificent proportions. It was resolved to take the ship round into the hitherto unvisited waters. On the north shore of the entrance, the green slopes which formed the foreground of the rugged heights of Cape Franklin were dotted with the small, burrow-like, forsaken winter dwellings of the inhabitants, whom some strange mutation of the climate had driven away, and afforded pasture to numerous herds of reindeer. From this point they steamed about 90 miles into the interior of Greenland; and had not the defective state of their boiler and the positive character of their instructions prevented them from risking a detention during a second winter, they might have easily advanced much further. From the summit of a peak (Mount Payer) 7200 feet in height, situated in 26° 18′ west long., a view was obtained of a mountain-chain lying about one third of the breadth of Greenland from the east coast, the loftiest peak of which must have been nearly 13,000 feet in height. No traces of a complete glaciation of the interior were visible. The usual magnetical, astronomical, zoological, and botanical excursions were here made. On the 17th of August, the expedition left the coast, and arrived at Bremerhaven on the 11th of September, 1870. During the whole voyage they determined the density of the sea-water, which was found to increase with the depth, especially amongst the ice. In regard to the 'Hansa,' from which they had been parted, notwithstanding the heroic efforts of her captain to reach the coast, she was nipped in the ice, and went down on the 23rd of October, 1869, leaving her crew to make an almost miraculous voyage of 800 miles on a constantly decreasing ice-floe, exposed to all the rigours of an Arctic winter. They were fortunately able, after at length leaving the ice-raft in their boats, to reach Friedrichsthal with the most incredible exertions.

On the Limpopo Expedition. By Captain F. Elton.

The lower course of the Limpopo was explored a few years ago by Mr. St. Vincent Erskine, the son of the Colonial Secretary of Natal; and Capt. Elton's object was to trace its higher waters, in order to see whether a more convenient route and water communication could be opened up from the settlement on the Tati river to the sea-coast, a distance of nearly 1000 miles. The difficulties, both natural and artificial, with which Capt. Elton had to contend were often very great; but the physical obstacles to his journey, and the hostility or cupidity of the natives, were successfully overcome; and he accomplished a voyage of considerably over 900 miles. He has also shown, as he believes, the practicability of the route he has opened up, and it is scarcely too much to expect that by so doing he has rendered essential service to commerce and civilization.

On a Self-replenishing Artificial Horizon. Invented and described by Christopher George, *R.N., F.R.A.S.*

This instrument consists of a pair of circular disk-like reservoirs about $2\frac{1}{2}$ in. in diameter and $\frac{3}{4}$ in. in depth, made of iron, at the same casting: one contains the mercury, and the other is the trough for observing.

The disks are connected at their circumferences by a narrow neck, in which is drilled a hole to allow the mercury to pass from one reservoir to the other; the communication between the two reservoirs is opened or closed by a stopcock, on the cone principle, so that the mercury can be passed from one disk to the other without removing the glass cover or the risk of losing any of the mercury. There are two screw stoppers attached to the mercurial reservoir for admitting air into

that reservoir or out of it as required. The trough-disk is fitted with a glass cover, which is screwed on when the mercury is to be passed to or from the other reservoir. When an observation has to be made this cover is removed, and a disk of glass is placed on the mercury; this gives a clear and steady reflecting surface. The weight of the instrument is $1\frac{1}{4}$ lb. The instrument is made by Messrs. Gould and Porter, successors to Cary, optician, No. 181 Strand, London.

Further disclosures of the Moabite Stone. By Dr. GINSBURG.

Ascent of the Atlas Range. By Dr. J. D. HOOKER, *C.B., F.R.S.*

In this paper the author described his ascent of the Greater Atlas, accompanied by Mr. Ball and Mr. G. Maw. Permission was given him to visit the whole range of the Atlas from a point eastward of the city, westward to the ocean; but he was obliged to promise to confine himself to collecting plants for the Royal Gardens and to practising as a Hakim, so that he was unable to take any exact topographical observations. He, however, reached the crest of the main range visible from the city of Marocco, which has long had the repute of being the loftiest of the whole great Atlas range. The mountains present, as seen from Marocco city, a long ridge, apparently of tolerably uniform height throughout its whole length, about 13,000 feet, steep and rocky in the upper regions, with long streaks of snow descending in deep steep gulleys; but it offers no snow-capped peaks or slopes of any extent, nor glaciers, and the loftiest points of the jagged sky-line are not snowed at all. The party took, from Marocco, first a south-easterly course to the foot of the Atlas, in the province of Misfuia, and thence a south-westerly one to the province of Reraia, whence they had been assured that the crest of the range was accessible. Their camp, at an elevation of 4400 feet, was surrounded by olive and walnut groves, fig-trees, prickly pears, vines, mulberries, and almonds. The native trees were poplar, ash, juniper, willow, and callitris (the famous Thuja of the Romans); the bushes are lentisks, honeysuckle, cistus, elder, rose, alaternus, phillyræa, ivy, bramble, and shrubs allied to the broom. The climate is temperate, and the scenery rather pretty than grand or mountainous, except up the valleys, which are backed by the rugged, black, but snow-streaked crest of the range. At 6000 feet the party came upon the first indubitable signs of old glacial action, in a huge moraine projecting apparently from the flank of a lateral valley, with two smaller moraines nearly parallel with the greater one. All were loaded with enormous blocks of porphyry and other metamorphic rocks, and, except for the walnuts and little terraced fields, are nearly bare of vegetation. At about 9000 feet they came upon a mule-track, up which they pushed over rocks and *débris*. Dr. Hooker and Mr. Ball were botanizing, and Mr. Maw alone reached the crest, where he read his aneroid, which gave a height, by comparison with another aneroid and the boiling-point, of 12,000 feet. The temperature was 24° F. The most remarkable feature of this part of the range is the downward extent of the snow in steep deep northern gulleys to 7000 or 8000 feet, up to the end of May; but these snow-streaks are not connected with any snow-fields or snow-capped peaks above. This seems to be due to the climate and to the steep contour of the axis, which is now scorched by a blazing sun, now swept by dry Sahara winds, and throughout the year exposed to the very prevalent N.W. oceanic wind laden with vapours that fall as snow and hail-storms. There is thus probably always snow on this part of the Atlas, but there is no perpetual snow proper; in other words, *all the snow that falls annually on fairly exposed surfaces melts in the same year*. Botanically, the upper region is as bare as the middle region is rich, and the author described in some detail the characteristics of each. The Atlas has a special interest as presenting the southern limit of the Mediterranean, and indeed of the North Temperate flora.

The party proceeded from the beautiful valley of Reraia westward over the northern spurs of the Atlas to the province of Sectana, whence they travelled on to that of Amsmiz, crossing the Wad en Fys, the principal feeder of the Temsift, where the author and Mr. Ball ascended a peak 11,000 feet high in the main range,

and from thence saw across the Sus valley to the southward. The snowy axis here approaches to within some fifteen miles of the foot of the mountains, and consists of more isolated tops and far less steep ridges, though snow came down to 8000 feet on northern exposures. The floor of the valley, like the others, is very narrow, and clothed with walnut and olive cultivation, threaded by a brawling stream. The valleys of the upper feeders of the Wad en Fys occupy an area probably not less than twenty miles broad. Dr. Hooker saw no forest in any part of the range, clumps of brushwood and isolated stumps of oak, juniper, carob, and ash being all that remain of the primæval woods. These mountains are extremely bare; even moss and lichens are poor and rare compared with what other alpine and subalpine regions present. Low as is the latitude of Marocco, its vegetation shows that the North Atlantic determines its climate, favouring the dispersion of northern types up to the tops of the Atlas, and forbidding the entrance of southern forms that elsewhere prevail in similar latitudes. From Amsmiz the party continued to travel along the base of the Atlas, and made some minor ascents, obtaining a general idea of the character of the chain in this longitude (8° W.), where there is another broad depression, through which the road runs from Marocco to Tarodant in the Sus valley—a place once of immense commercial importance, and still one of great resort. The party returned to Mogadore on the 3rd of June, and succeeded in bringing their collections safely with them, which will enable Dr. Hooker to elucidate the flora of a hitherto almost unknown region. The Moors and Arabs of Marocco are described as being vile beyond a proverb. The Government is despotic, cruel, and wrong-headed in every sense. From the Sultan to the lowest soldier all are paid by squeezing those in their power. Marocco itself is more than half ruinous, and its prisons are loaded. The population of the whole country is diminishing; and what with droughts, locusts, and cholera, and prohibitory edicts of the most arbitrary description, the interior is on the brink of ruin. But that two thirds of the kingdom is independent of the Sultan's authority, being held by able mountain chiefs who defy his power to tax or interfere with them, and that the European merchants maintain the coast trade, and the Consuls keep the Sultan's emissaries in check, Marocco would present a scene of the wildest disorder.

A Journey from Yassin to Yarkand. *By* Ibrahim Khan.

Interior of Mekran. *By* Captain B. Lovett.

Note on the Geographical Distribution of Petroleum and allied products. *By* Colonel R. Maclagan, *R.E., F.R.S.E., F.R.G.S.*

The extent and variety of the uses to which petroleum and other allied products have come to be applied, and the vast quantities in which, within the last few years, they have been obtained, give a special interest and importance to the observation of their geographical range and positions. The places are numerous, and the circumstances varied, in which these substances, in some one or other of their forms, have for long ages been known.

The classification of these products having certain general common characters, and probably a similar origin, is not now essentially different from that of Linnæus, and exhibits relationships before recognized in a less formal and systematic way by Pliny and others*. They belong to Linnæus's class of "inflammable minerals," consisting, according to his arrangement, of bitumens, coals, amber, and ambergris. The bitumens he specifies as fluid bitumen or naphtha, rock-oil or petroleum, mineral tar or maltha, mineral pitch or múmia, asphalt, mineral tallow, elastic bitumen, and hard bitumen or jet. And next to the bitumens and coals he places honey-stone (found associated with asphalt), common amber, and ambergris. Prof. Archer, in a paper on the oil-wells of Pennsylvania and Canada (Art

* Pliny, N. H. lib. xxxv.; Strabo, xvi.; Herod. vi. 119, &c.

Soc. Journ. Aug. 1864), says, "It may be useful to know that rock-oil, petroleum, Barbadoes tar, naphtha, are all varieties of the same material, and that bitumen is the pitch-like residue which remains after the refined oil is distilled from the crude, or has naturally dried away." These are the substances of which collectively the geographical positions are to be noticed.

The notices in old writers of the well-known sources of bitumen on the Euphrates and in Judæa are numerous, and these are the most frequent subjects of reference to these products in later times, till the remarkable naphtha-springs at Bákú on the Caspian, and the striking appearance which they present, came to be more generally known. The soft bitumen in the Euphrates valley is that of which we have the earliest mention *. The word translated "slime" in the English version of Gen. xi. 3, is *ἄσφαλτος* in the LXX. and *bitumen* in the Vulgate, and this is what is meant. Of the asphalt of the Dead Sea, its quantity, and the magnitude of the masses frequently found, there are many accounts in the writings of ancient and modern travellers †.

The great abundance of the petroleum at Bákú on the Caspian, and the remarkable sight presented by the flaming streams of oil and discharges of gas, have been the subject of many descriptions. One of the chief things of note at Bákú is this emission of inflammable gas or naphtha-vapour, which occurs also in many other parts of the world, with or without the immediate accompaniment of oil-springs.

The fire-temple at Bákú has a special interest in connexion with India, not only from its general similarity to that of Jwála-Múkhi near Kangra in the Punjab, but also from the circumstance that the Bákú temple has, for a long time and down to the present day, been, like the other, a place of Hindoo pilgrimage, and maintains a small fraternity of resident Brahmans. The great conflagrations of oil on the surface of the ground have not been constant, and many travellers do not mention them; but they could not fail to have been mentioned by any who had seen them ‡.

Marco Polo describes the great abundance of the discharges of oil at Bákú, and says that people came from vast distances to fetch it §. Bákú is described by Kaempfer, who was there in January 1684 ||. Just a hundred years later it was visited by Mr. Forster on his journey from India to England. He has given a detailed and interesting account of the place, and of the Hindoo mendicants and merchants who resided there. He mentions that the Hindoo traders there were chiefly from Mooltan, and that they usually embarked at Tatta in Lower Sind, proceeding by sea to Bussora, and thence accompanying the caravans passing into Persia. I made endeavour to ascertain at Mooltan whether there is at the present day any direct intercourse between the Hindoos of that place and Bákú, but could not learn that it is kept up. But it is very possible that enterprising Hindoos from Mooltan who do not return there, and whose movements are not known to their friends, may settle down at Bákú as they do elsewhere. A Punjabee Hindoo died a few years ago at Moscow, regarding whose property in Russia and relations in the Punjab there was some correspondence between the Russian Government and our own in India and in England. Among the Hindoos at the Bákú temple Forster ¶ found an old man, a native of Delhi, who had visited all the celebrated temples of northern and southern India, and whom he afterwards met at Astracan. Morier, in 1812, met in Persia a Hindoo entirely alone, returning to Benares from a pilgrimage to Bákú **.

About midway between Kaempfer's time and Forster's, came Jonas Hanway, who gives a description of Bákú, the fire-temple, and the Hindoos, and the great quan-

* Herod. i. 179; Philostr. Apoll. Tyan. i. 17; D'Herbelot, Biblioth. Or. s. v. Hit.

† Strab. vi. 763; Plin. N. H. vii. 13; Joseph. B. J. iv. 8. 4; Tacitus, Hist. v. 6; Maundeville, Rochon, &c.

‡ "... *Bâdkû* and those fountains of blue flame
That burn into the Caspian."—Lalla Rookh: *The Veiled Prophet.*

§ Book I. ch. iii. (vol. i. p. 46, of Col. Yule's edition, 1871). See also note in Marsden's edition.

|| Amœnit. Exot. p. 274, &c.; Lives of Celebrated Travellers (Colburn's Nat. Libr.), i. 263.

¶ P. 262, note.

** Second Journey, p. 243.

tities of oil, obtained then chiefly from certain islands in the Caspian. Descriptions are given by other old and modern travellers of this oil-region, the copious discharges of the white and black naphtha, the streams of flaming oil on the hill sides, the gas and the fire-temple, and the explosive effects of the ignition of the gas mixed with atmospheric air *. An interesting communication was made in 1868 to the Geographical Society of Paris by Dr. Boerklund on the results of his trans-Caucasian explorations, in which he describes the naphtha-regions of the Caspian. On the Ile Sacrée, he mentions, not far from the Abscheron peninsula on which stands Bákú, there is now a manufactory of paraffine.

Dr. Boerklund notices also the association of these petroleum-fields with active mud-volcanoes. The connexion of petroleum with eruptions of mud and agitations of the earth's surface is noteworthy and important †. The most complete observations on mud-volcanoes, and the relation of these and similar phenomena to deposits of petroleum, are to be found in Prof. Ansted's paper on the subject communicated to the Royal Institution in May 1866, with immediate reference to the mud-volcanoes of Sicily and the Crimea which he had recently visited. There are mud-volcanoes in other parts of the world, in connexion with which petroleum has not hitherto been found. There are large volcanoes of this kind at Hinglaj near the south coast of Belochistan, which have been visited by a few British officers. So far as I am aware, no signs of petroleum have been found in their neighbourhood; but the country has not been well explored ‡. The petroleum of Kerman has been noticed by Pottinger §. One of the allied substances, ambergris, has long been a noted product of the adjacent seas.

The similarity of the phenomena shown by mud-volcanoes and gas-springs in the Italian peninsula, in the Caucasus, and in South America, is displayed over great tracts of country in the Chinese Empire ||. The use of the natural fires of petroleum and gas in the province of Shan-Si is described in an old account of the province by a native writer, Dionysius Kao, who says that in all parts of the province are fiery wells, which conveniently serve the people for cooking their victuals. (Possibly the "Temple of the Limit of Fire," mentioned by Fa Hian the Chinese Buddhist pilgrim, was a temple over natural gas-flames like those of Bákú and Jwála-Mukhi ¶.) Similar gas-flames on the Caramanian coast are described by Capt. Beaufort **, as before by Pliny.

The country from which the principal supplies of petroleum were obtained in Britain, previous to the discovery of the enormous quantities to be obtained in America by boring, was Burmah. Of the petroleum wells in that country a full account is given in Colonel Yule's 'Narrative of the Mission to the Court of Ava,' and in the notes in the Appendix by Mr. Oldham, Director of the Geological Survey of India. In the Province of Pegu there is a burning hillock called the Nat Mee or Spirit Fire, of which an account is given by Lieut. Duff, Deputy Commissioner of Thyet Myo, in a communication to the Asiatic Society of Bengal, July 1861. The gaseous exhalations at Chittagong, called the Burning Fountains of Brahma, have been described by Turner, and more recently by a writer in the Journal of the Asiatic Society of Bengal ††.

There are many other parts of Asia and Europe in which these products, in some of their forms, are found and have long been known. In Assam petroleum is now obtained in considerable quantity by boring. The native petroleums of Southern India and of Australia have been shown in recent local exhibitions. In the interior of Sumatra springs of sulphur and petroleum were discovered in 1869. The petroleum of the north-western parts of the Punjab, known

* Wonders of the East, by Friar Jordanus (Col. Yule's note), p. 50; Hon. G. Keppel's 'Journey from India to England,' 1824; 'A Journey from London to Persepolis,' by J. Ussher, 1865; Morier's Journey; Kinneir's 'Persia,' &c.; 'Some Years' Travels,' by Tho. Herbert, 1638.

† Cosmos, i. 212; Scrope on Volcanoes.

‡ An account of them by Col. A. C. Robertson, 8th Regt., is given in the Journal of the Asiatic Society of Bengal, 1849.

§ P. 312.

|| Humboldt, 'Cosmos,' iv. 216; Huc, 'Chinese Empire,' ch. vii.; Davis's 'Chinese,' chap. v.

¶ Beal's 'Buddhist Pilgrims,' ch. xvi. p. 68.

** Cosmos, i. 210.

†† Vol. xii. p. 1055.

and used since an early period *, is now being worked. The chief purpose for which it is directly required is the manufacture of gas for one of our large military stations (Rawul-Pindee).

The great vigour and vitality of the flame of petroleum gave it a special value as a material for igneous missiles before the invention of gunpowder. It is only necessary here to notice this application of the mineral oils as indicative of the localities from which the material was probably obtained †. The Levant, the coast of Asia Minor, the Grecian islands, Sicily, and the Caspian, would furnish abundance of this material in some of its forms for the destructive engines and fire-balls used in the Eastern wars and sieges. There is good reason to believe that the Punjab petroleum was applied to a similar purpose by Mahmúd, of Ghazni, in one of his engagements near the Indus with the Indian prince Anandpal in the beginning of the 11th century. This question has been discussed in a most interesting note on the early use of gunpowder in India by the late Sir Henry Elliot, in the first volume of his 'Bibliographical Index to the Mohammedan Historians of India' ‡.

The substance called múmia, or múmiái, is held in great estimation as a medicine for both internal and external use. The other substances of the same class are also used for medicinal as well as for other purposes §; but what is called múmia is used for this only. The current belief in the East is that múmia is of animal origin. It is worthy of note that recent researches have led to the conclusion that this is the case with respect to some, at least, of the great deposits of the mineral oils discovered within late years; but the animal origin of múmia is, in Persia and India, believed to be more immediate. That obtained in the shops at Lahore is said to come from Cabul, that is, in a general way it is obtained from or through Afghanistan. Dr. Fryer tells of a place in Persia where it was obtained in his time ||. Petroleum is abundant in the same quarter now. Another of the substances of this class, ambergris, has at all times been believed to belong, mediately or immediately, to some big animal of the salt water; but the conclusions regarding it are not even now very satisfactory ¶.

The geographical positions in which these various products in some of their forms are found, and in which indications of their existence, or the frequent accompaniments of them, are met with, appear to be sufficiently varied. They occur in great river-basins, in those of the Euphrates, the Indus and its tributaries, the Brahmaputra, the Irawádi; of the St. Lawrence in Upper and Lower Canada, the Ohio and Mississippi in the States of Ohio, Tennessee, and Arkansas, the Rio Colorado and other minor rivers in California and New Mexico. Next, we observe them very abundant in the two remarkable depressed lakes, the Caspian and the Dead Sea. In islands, Ceylon, Sicily, Zante, and other of the Greek islands, in Sumatra, and in a special manner in Trinidad near the mouths of the Orinoco. Along the skirts of great mountain-ranges and between mountain-ranges and the sea; thus in Pennsylvania and Virginia, in the country on either side of the Alleghanies; in Tennessee, intersected by the Cumberland mountains; in Texas, with its broken ranges of mountains parallel to the coast, and large rivers running from them and through them into the Gulf of Mexico; between the mountains and the sea in the south of Asia Minor, of Persia, and Belochistan.

* Notices of it are given in the works of Elphinstone, Burnes, Vigne, Edwardes, and others.

† Accounts of the nature and effects of such missiles are given in De Joinville's 'Life of St. Louis,' and in the pages of Gibbon, Niebuhr, Hallam, &c., and more particularly in Messrs. Reinaud and Favé's Treatise on the 'Feu Grégeois.' See also Ammian. Marcell.; Vegetius, 'De Re Militari;' Tasso, 'Jer. Del.' xii. 42–44.

‡ The *fire-pao* mentioned by Polo, the *agni-aster* of the ancient Hindoo poems, and the fire-darts referred to by Menu, have possibly been of the same kind.

§ Hanway; Abbé Huc, 'Chinese Empire,' ch. xi.; 'Indian Annals of Medical Science,' no. iii. 250; Ainslie, 'Materia Indica,' i. 41; Honigberger, 'Thirty Years in the East,' &c.

|| New Account of East India and Persia, nine years' travels, 1672–1681, by J. Fryer, M.D., p. 318.

¶ Lane's 'Thousand and One Nights,' iii. 66; Yule's 'Marco Polo,' vol. ii. p. 342; Renaudot, 'Ancient Accounts of India and China,' p. 94.

In all these various kinds of geographical situation they are found, their production and exhibition being subject to necessary geological and other conditions, on which it is not the purpose of this paper to enter.

The frequent association of these products with salt has been noticed. The oil-fields of the Punjab, which have lately been surveyed and reported on, are all in the north-west part of the broken series of hills and tract of country bearing the general name of the Salt Range, containing the inexhaustible stores of massive salt from which that province and neighbouring countries have been supplied for many centuries. The explanation of the connexion of salt with petroleum has yet to be sought, but the fact meanwhile is important.

The oil is not always accompanied with gas, but the inflammable gas appears generally, if not always, to indicate the existence of the oil in some form, and particularly, as it appears, in regions producing salt.

The oil is obtained, as in Burmah, by making excavations in the soil in which it has become diffused, into which excavations or wells the oil slowly passes from the soil around. And it is procured by deep borings, in which it may rise in the manner of water in artesian wells, by hydrostatic pressure, or, as in the many instances with which descriptions of American and other oil-wells have made us familiar, forced up from reservoirs in subterranean cavities under the pressure of steam or other vapour. In any geographical situation it may be obtained in the first manner. It is when it occurs along the outskirts of mountain-ranges that it may rise as in artesian water-wells; and where the earth has been subjected to violent internal action, and the rocks have been much split and displaced, it is obtained from cavities and veins, frequently attended with escape of gas at the surface of the ground and spontaneous discharges of the oil.

These appear to be, in a general way, the kinds of situation and the modes in which, where these products have been formed, they are obtained for use, or where the surface-indications of their presence occur. It is desirable that further and more definite information should be gathered by those whose experience of oil-regions, or other opportunities, afford them the means of contributing to our knowledge of a subject which has come to be of great practical importance as well as of scientific and general interest.

On the Formation of Sand-bars. *By* Dr. R. J. MANN.

Report on Badakshan. *By* PANDIT MANPHAL, *C.S.I.*

On the Eastern Cordillera, and the Navigation of the River Madeira. *By* C. R. MARKHAM, *C.B.*, *Sec. R.G.S.*

The author began by referring to the paper which he read before the Association at the Leeds Meeting in 1858, and in which he showed the vast importance of the opening up of lines of water communication between the Andes and the Atlantic by way of the Amazons, and the immense extent of country which then remained to be explored. Having pointed out what has since been done in the way of discovery, he proceeded to give an account of the recent investigations connected with that portion of the mighty eastern Cordillera of the Andes which contains the sources of streams that form the Beni, and to report upon the operations which are in contemplation, with a view to opening a navigable route from the Beni to the Atlantic by way of the river Madeira. The old Yncas of Peru did all that was possible to secure for their people the wealth of those interminable forests to the eastward of the Andes, but they did not know that the rivers dashing down from their mountains led to an ocean whence the arts and products of the whole world might be brought to their doors. But their descendants see, in the mighty Amazon and her tributaries, a means of saving the ruinous land-carriage of their merchandize to the Pacific coast. The cost of taking a ton of merchandize from Cuzco, the capital of the Yncas, or from La Paz, the commercial capital of Bolivia, to England, is about £40, the time five months. Under such conditions no produce but gold, silver, and chinchona bark would pay the expense

of transit. By the route of the Madeira and Amazons, this voyage of five months will be reduced to six weeks, the course being through a civilized empire which takes the lead in opening the way for the commerce of the world; while the opening of those great fluvial highways will also have the effect of solving the most interesting questions in South American geography. The section of the Eastern Andes, which is drained by the feeders of the Beni, extends from the parallel of Cuzco to that of La Paz. This eastern chain forms a giant wall, running up into the loftiest peaks of South America in its southern portion, and everywhere rising above the line of perpetual snow. The author showed that the cartography of the south-eastern end of the chain is well defined in our best modern maps, while that of the north-western portion is in a state of much confusion; and he also pointed out some analogous features which exist between the Andean and the Himalayan ranges. He then described in some detail the physical features of the region, which is peculiarly interesting, leading to the conclusion that the complete examination of the great affluent of the Madeira will result in opening up one of the richest countries in the world, provided that the question of turning the rapids of the Madeira, and of making the lower part of its course navigable, is grappled with and overcome. The Brazilian Government is alive to the importance of developing the resources and fostering the trade of the Amazon valley, and has caused an elaborate survey to be made of the Madeira rapids. These are eighteen in number, the total fall being 272 feet. The length of the river course, containing rapids, is 229 miles, and the length of actual broken water is 12 miles. The difference between low water and floods is about 20 feet, the rise commencing in October and ending in March. Commerce is now carried past in launches and canoes carrying from 3 to 8 tons. At six out of eighteen rapids it is necessary to haul the boats round overland, at five others the boats are hauled up stream while the boats are carried round, and the rest are merely difficult passes where the loaded craft easily shoot along the current. Serious steps have now been taken to overcome these obstacles. A concession has been granted for the construction of a railway round the rapids, which will be 170 miles long, including a short branch to the mouth of the Beni. Above the Madeira rapids there are 3000 miles of river suited to steam navigation; and the articles of commerce, which would at once find an outlet by this route, are Chinchona bark, India-rubber, vanilla, sarsaparilla, balsams, aloes, valerian, dye-woods, gums, wax, hammocks and bats, cacas, coffee, hides and tallow, wool, skins, cotton, gold, silver, and copper. Commerce is already treading close on the heels of discovery; and Peruvian bark, hitherto shipped exclusively from Pacific ports, is now beginning to find its way to England by the Amazon and Pará. The trade of the Amazons, which was less than half a million when the steamers began to run in 1853, is now upwards of £2,000,000; and this only represents the traffic on the main stream. The increase will certainly be enormous when the mighty affluents bring down the products of the Andes to find their way, by this magnificent fluvial highway, to the Atlantic. The country is one possessing boundless capabilities, and a bright future must assuredly be in store for that great Amazonian basin which nature has blessed so wonderfully. Nothing can be more likely to conduce to the consummation of its commercial greatness than the thorough examination of those splendid navigable rivers which form the chief affluents of the Amazons, and some of the more important of which are still so little known. In no other part of the world is there a grander field for geographical discovery and research. In no other part will the labours of the explorer be more richly repaid.

On the Geographical Positions of the Tribes which formed the Empire of the Yncas. *By* Clements R. Markham, *C.B., Sec. R.G.S.*

In submitting to the Section the views which a study of early writers, the native languages, and the topography of the country had led him to form respecting the geographical positions of the tribes which combined to form the empire of the Yncas of Peru, the author pointed out that the study of the nature and degree of the civilization attained by the aboriginal Americans is especially important, because that civilization was self-developed. The three American empires of the

Yncas, the Chibchas, and the Aztecs were based upon the progress made in the arts of civilization by the tribes which composed them, and on the united efforts of those tribes, after they had been welded into great nations. The difficulties of classifying or distinguishing the special characteristics of the component tribes having been shown, a description was given of the region which formed the empire of the Yncas. This vast tract is a long strip of mountain- and coast-line, bounded on the east by the forest-covered plains of the Amazonian basin, on the west by the Pacific Ocean, and extending north and south from 2° N. to about 20° S., or upwards of 1500 miles, with an average width of 400 miles. It comprises every variety of climate, and contains within its limits the most prolific tropical forests, valleys with the climate of Italy, a coast-region resembling Sind or Egypt, temperate hill-sides and plateaux, bleak and chilling pasture-lands, and lofty peaks and ridges within the limits of eternal snow. On one mountain-side the eye may embrace, at a single glance, sugar-cane and bananas under cultivation in the lowest zone, waving fields of maize a little higher up, shaded by tall trees, orchards of tropical fruits, stretches of wheat and barley, steep slopes clothed with potatoes and quinoa, bleak pastures where llamas and alpacas are browsing, and rocky pinnacles streaked with snow. In such a country, with such a variety of climates and products, and where communication is so difficult, the various nations appear to have gradually developed their capabilities in almost complete isolation. The tribal divisions of the empire of the Yncas agree well with its leading physical aspects. They consist of five clearly defined regions, four following the lines of the Cordilleras, and the fifth on the sea-coast. The first and most northern extends from the river Ancas-mayu to the knot of Loxa, a distance of 350 miles, and is included in the kingdom of Quitu. The second reaches from the mountain-mass of Loxa to the saddle which separates the drainage of the Huallaga and Ucayali. It is 450 miles long, and comprises the Ynca division of Chinchasuyu. The third and most important region is that which is drained by affluents of the Ucayali. It includes the home of the imperial tribe, and may appropriately be called the Ynca division. The fourth comprises the basin of Lake Titicaca, and is known as the Collao. The fifth is the coast-region, and extends along the shores of the Pacific, from the Bay of Guayaquil to the desert of Atacama, a distance of 1200 miles. There is no sufficient evidence for the belief that the Yncas originally came from a distance, and there is a native tradition to the effect that their civilization was altogether of indigenous origin and growth. The author referred successively, and in considerable detail, to the religion, the language, and the architecture of the Yncas, which afforded evidence of, and an index to, the progress of civilization among the tribes. He also briefly described the different regions which comprised the empire, and gave some account of their history and peculiar characteristics. The conclusion arrived at, after careful study, was that the tribes of Peru resolve themselves into two primary divisions, distinguished by a complete difference of language, both as regards vocabulary and grammatical construction, sufficient to establish an entirely separate origin. These are the people of the four Andean regions, and the Indians of the coast. They form two races and two civilizations. The tribes of the four Andean regions, on the other hand, spoke languages which, though differing as regards vocabulary, are identical in grammatical construction, and point to a common origin. The languages are our most reliable guides. Physical differences are caused by local circumstances connected with climate and habits of life. But the languages, when carefully studied, give us an insight into the original condition of the different tribes, and, with the aid of evidence collected from the earliest writers, enable us to resolve the great Ynca Empire into its elements, and to classify its component parts. In a geographical point of view it is important that we should be able to indicate the exact positions occupied by the different tribes, as well as their relative importance, and the degree of relationship they bore to each other.

On the Somali Coast. By Capt. Miles.

This paper contained information regarding the country and its inhabitants, as well as the trade in gum and aromatic spices, in which the natives have engaged

from a very early period. The Somali country is but thinly peopled, the tribes being purely nomadic, raising no corn, but subsisting on their flocks and herds, and moving about for the convenience of pasturage.

Encroachments of the Sea on the East Coast of Yorkshire. *By the* Rev. F. O. Morris.

On the Inundation and Subsidence of the Yang-tsze River, in China. *By* S. Mossman.

The author described the phenomena attending the annual floods of the Yang-tsze-Kiang, which are similar to those of the Nile, but greater in inundation, and more devastating in effect. The floods depend upon rainfall from clouds caused by the south-west monsoon rising in the Indian Ocean, and the melting of snow in Eastern Thibet and Kokonoor, where the tablelands are from 12,000 to 13,000 feet above the level of the sea. So far the origin of the floods in the Yangtsze-Kiang is similar to that of the Nile, but the rise and subsidence of the former river are more rapid than those of the latter. The inundations vary more or less in their height from year to year, the range being from thirty-five to fifty feet, while the most frequent rise is about forty feet.

Letters from Vladivostok and Nikolsk, South Ussuri District. *By the* Archimandrite Palladius.

On the Geography of Moab. *By* E. H. Palmer, *M.A.*

The author commenced by describing the country of Moab, which is about fifty miles long by twenty broad, and includes the tableland on the eastern shore of the Dead Sea, as well as that part of the Ghor which lies on the eastern bank of the Jordan opposite Jericho. The uplands he described as consisting of a rolling plateau, about 3200 feet above the level of the sea, the western edge being cut up into deep valleys, and descending by a series of sloping hills, at angles of forty-five and fifty degrees, into the Dead Sea. These uplands are naturally divided into two districts by the great chasm of Wády Mojib, the Arnon of Scripture. The author gave some interesting instances of his identification of modern places and terms with those mentioned in Scripture history. For instance, he stated that the modern town of Kerek, though little better than a collection of hovels, stands upon the site of the ancient capital of Moab. In the Old Testament it is called Kír-Haraseth,—Haresh, or Heres. The first part of the name appears to signify "a walled city," but the meaning of the suffix has sufficiently puzzled commentators. But when the author was at Dhibán (the ancient Dibon), he unexpectedly met with an explanation of this term, and it is very curious as an example of the striking manner in which apparently trivial local idioms and customs often illustrate the phraseology of the Bible. Asking one of the Arabs where the Moabite stone was found, the latter replied that it was "between the harithein," that is, between the two háriths. Now, in Arabic this word would mean a ploughman, and when the author asked for a further explanation, the Arab pointed out the two hillocks upon which the ruined village of Dhibán stands, and between them lay the fragments of the broken monument of Mesha. Nearly all the towns in Moab are built upon similar eminences, and the author found that they are invariably called Háriths by the Arabs. The word "Harith" is precisely equivalent in orthography to the *haresh*, or *hareseth* of the Bible; and thus, in an apparently insignificant idiom, is seen an unexpected illustration of the topography of the Bible,—an additional reason for identifying the modern Kerek with the ancient *Kír-hareseth* ("the city on the hill"), and the interesting discovery of a local Moabite word handed down from the time of Jehoram, son of Ahab, to the present day. The author gave several other curious instances of this kind of identification, and described at some length the investigations of Capt. Warren, Mr. Tyrwhitt Drake, and himself.

On an Acoustic Phenomenon at Jebel Nágús, in the Peninsula of Sinai. *By* Captain H. S. Palmer, *R.E.*

Jebel Nágús is the name given to a high sand-slope in the western coast-range of the peninsula of Sinai, about five miles north of the port of Tor. The sand of this slope possesses the peculiar property of giving forth loud musical sounds when set in motion by design or by natural causes. According to a quaint native legend, founded on the former monastic occupation of this part of the peninsula, the sounds are said to proceed from the *nágús*, or "wooden gong"*, of a monastery buried beneath the sand. Hence the application of the name Nágús to the slope in question.

The sand-slope is about 200 feet high, and 80 yards wide at its base, narrowing towards the top; it faces west-south-west. Sandstone cliffs overhang it, and bound it on either side, and an open sandy plain stretches from the foot of the slope to the sea-shore, about three-quarters of a mile distant. The sand of the slope appears to be that from the neighbouring desert plain, derived in the first place from the waste of the sandstone rocks, and then conveyed to its position on the hill-side by the drifting action of high winds; its grains are large, and consist entirely of quartz. The rock *in sitû* is a soft friable quartzose sandstone, of a pale brown inside, and weathered externally to a dull dark brown. The sand of the slope is so clean, and in its usual condition so extremely dry, and inclined at so steep an angle (about $29\frac{1}{2}°$) to the horizon, that it may be easily set in motion by such causes as the passage of men or animals across it, falling *débris* from the cliffs above, or disturbance by the wind. Sometimes also movement on a smaller scale may arise from an abnormal excess of heat and drought, or from the separation of the surface-particles, after their consolidation by rain or dew, on the return of heat and the sun's burning rays. When any considerable quantity of the sand is in movement, rolling gradually down over the surface of the slope in thin waves an inch or two deep, just as oil or any thick liquid might roll over an inclined sheet of glass, and in similar festoons or curves, then is heard the singular acoustic phenomenon from which the hill derives its name, at first a deep, swelling, vibratory moan, rising gradually to a dull roar, loud enough, when at its height, to be almost startling, and then as gradually dying away, till the sand ceases to roll. The sound is difficult to describe exactly; it is not metallic, not like that of a bell, nor yet that of a *nágús*. Perhaps the very hoarsest note of an Æolian harp, or the sound produced by drawing the finger round the wet rim of a deep-toned finger-glass, most closely resembles it, though there is less music in the sound of the rolling sand: it may also be likened to the noise produced by air rushing into the mouth of an empty metal flask; sometimes it almost approaches to the roar of very distant thunder, and sometimes it resembles the deeper notes of a violoncello, or the hum of a humming-top. The author found by experiment that hot surface-sand was more sonorous than the cooler layers beneath; it also seemed to run more quickly; the first experiments on any one part of the slope produced louder effects than subsequent ones. Surface-sand, at a temperature of 103° Fahr., exposed to the sun's full glare, produced the grandest effect observed, while sand in shade, at 62°, was almost mute. By day the heat on the slide is generally very great. Movement of the sand when moist is not accompanied by unusual sounds. Excavation was impossible, on account of the continuous flow of the sand when disturbed; in some places nothing solid could be reached by probing; in others, rock was felt a few inches below the surface, but whether *in sitû* or not could not be ascertained. When sand is rolling down and producing sound, there is a distinct vibration on the slide, increasing with the intensity of the sounds. Throughout Capt. Palmer's stay, the wind blew from N.W.; the effects produced on the slide by winds from other quarters have yet to be observed. Experiments on two other sand-slides, a little to the south of Jebel Nágús, and resembling it in many particulars, did not result in producing any similar sounds. But phenomena of a kindred character had been noticed in other parts of the world, as, for instance, at Reg-Raván forty miles north of Cabul, and on the sandy plains of Arequipa in Peru.

Jebel Nágús had been several times visited and described, but the author had

* Used in place of bells in convents of the Greek Church.

had better means and opportunities for investigation than those of previous travellers, and he submitted this paper in the hope of once more inviting attention to a curious and interesting subject. There could be no doubt that the sound arises from the movement of the surface-sand, and is intimately connected with the siliceous character of the sand and its extreme dryness, but the author was not aware that any exact explanation of the phenomenon had as yet been elicited from scientific men.

Notes on British Gurhwal. *By* Capt. A. Pullan.

The Saskatchewan Valley. *By* Dr. Rae.

On the Volcan de Agua, near Guatemala. *By* W. B. Richardson.

A Journey through Mekran. *By* Major E. C. Ross.

On the Topography of Ancient Jerusalem. *By* George St. Clair.

On the Himalayas and Central Asia. *By* Trelawney Saunders.

On Trade Routes between Burmah and China. *By* Major Sladen.

The author explained that the object in view in all explorations undertaken in Burmah had been a desire on the part of our Government and mercantile classes to ascertain the practicability of establishing an overland route from the Bay of Bengal to Central and South-Western China. Major Sladen referred to the expedition which he conducted up the Irawadi a few years ago, and pointed out the practicability of navigating this river nearly, if not quite, up to the Chinese frontier. At Bhamo, 900 miles from the sea, and probably 1000 miles from its source, the Irawadi, when full between its natural banks, is four miles in breadth, and during a third of the year or more it might be navigated with the greatest ease as far as Bhamo, by vessels as large as any that have ever ascended the Yangtsze, from Shanghai to Hankow. By selecting the Irawadi as a means of transit for produce from South-Western China, and Rangoon as a port of export for such produce, the voyage to Europe, both in distance and duration, would be reduced in a correspoding degree, the expenses of navigation would be reduced, the risks and dangers attending difficult navigation through the straits of Malacca and the China seas avoided, and the heavy insurances at present in force by reason of such difficult navigation would be altogether done away with.

On the Proposed Ship-Canal between Ceylon and India. *By* Commander A. Dundas Taylor.

This officer, having given much attention to the study of Indian hydrography, devoted a portion of his paper to an historical sketch of the discussion which has been going on more or less during the whole of the present century regarding the practicability of forming a navigable passage between the Gulf of Menaar and the Bay of Bengal. The project of deepening the Paumben Passage for the navigation of large ships did not commend itself to Commander Taylor's approval. Sir James Elphinstone, as a practical seaman, had personally investigated this channel, but had come to the conclusion that it would never do for large ships. But during his examination of the neighbourhood in concert with Captain Dorman, Master-Attendant of Colombo, Sir James discovered a well-sheltered area of anchorage, with soundings of five or six fathoms, extending over five square miles, and thence

gradually decreasing to four fathoms about half a mile from the Indian shore, where the canal's mouth is proposed to be. This harbour lies between Mostapetta Point and Moosel islet, lengthways on the plan; whilst its north and south limits are respectively at Poonamudum town and Moolee islet, the entrance, in which there is now a depth of three fathoms at high water, being about a mile and a half to the east of the last-named islet. The anchorage is well protected against the southerly swell of the monsoon by the coral islets and connecting reefs, extending from Valinookam Point to Rameswaram.

On the American Arctic Expedition. By Capt. WARD, *R.N.*

Exploration of the Headwaters of the Marañon.
By M. ARTHUR WERTHERMAN.

Captain Garnier's Expedition up the Camboja.
By Colonel HENRY YULE, *C.B., President.*

In this paper the author described the progress of the French Expedition up the Camboja river, which was sanctioned in the end of 1865 by M. Chasseloup-Laubat, then Minister of Marine, and also President of the Geographical Society of Paris. The object of this Expedition was to discover the nature and resources of the region in which the French had planted a colony, and also to extend French influence in that direction. But few Europeans had previously ascended the river, so that the Expedition had practically a virgin field for exploration. The party started from Saigon on the 5th of June, 1866, and included Capt. De la Grée, the chief, Lieut. Garnier, second in command and geographer, Thorel and Joubert, navy surgeons and naturalists, Delaporte, a young naval officer, as artist, and De Carné, a young civilian. There were also four European soldiers and sailors, but they were all eventually sent back, and natives employed in their stead. Proceeding first to the neighbourhood of Udong, near the Great Lake, as it is called, they then directed their course to Cratieh in 12° 28′, distant 300 miles from the mouth of the river. Here they took to canoes for the ascent, which was at first favourable, but was afterwards rendered difficult by rapids and cataracts, the river being also broken by a vast number of islands. Above the cataracts the channel became narrower, and the islands gradually ceased. Difficulties with regard to passports were also felt, and a variety of causes rendered travelling backwards and forwards several times imperative. Instruments also that were necessary to success, and that had been promised them, had not arrived, and now, to add to their troubles, an insurrection broke out which closed the river below. Lieut. Garnier volunteered to make his way by land to the Delta, where it was expected that both passports and instruments would be found. He started on the 10th of January, 1867, and, after a perilous journey, reached the French gunboat stationed on the frontier. The passports were found, though the instruments were still missing; and on the 8th of February Garnier once more started for the upper country. On the 10th of March he rejoined his party at a place called Huten, in the province of Khemarat, having travelled something like 1100 miles since quitting them. This fatiguing journey has added a large and before quite unexplored tract to the surveys resulting from the Expedition. On quitting Huten, the river turns more and more westward and forms the first immense elbow, hitherto quite unsuspected (running east and west for nearly 4° of longitude), in about the latitude of 180° north. As far as Vienchang, the country traversed by the river is an immense plain, rarely broken by a few mountain-ridges. A short distance above Vienchang, the Mekong is found definitively shut in between two ranges of hills, and instead of its breadth being measured by miles, it is contained in a channel of 500 or 600 yards wide. Having got on the borders of the Ava territory, the party found that their most serious difficulties commenced. The Burmese officials offered obstructions, and the rainy season added severely to the fatigues of the way, while the extortions of the natives caused them additional trouble. But at last they reached Kiang Hung,

where new efforts were made to stop their further advance. In October, however, they were enabled to start once more for Tsemas, the first stage in China, that country to which they had so long looked forward as the Promised Land. The Mekong was here finally quitted. The Expedition had to deviate eastward, and came upon the Yuen Kiang, or River of Tonking. Garnier explored this river as far as the Anamite frontier, and rejoined his party at Linggan. From Linngan-fu the Expedition proceeded direct towards Yunnan-fu, traversing a lake-region of great interest. On quitting the valley of the Tonking river they commenced ascending a plateau of 5000 to 5600 feet in height, on which they found growing most of the fruits and other vegetable products of Europe. They arrived at Yunnan-fu on the 23rd of December, 1867. Thence they set off by a devious course (the country between being ravaged by hostile armies) for Tali; but Capt. De la Grée falling sick, the leadership of the expedition was given to Lieut. Garnier, Dr. Joubert being left in charge of the chief. Through a difficult country, by the aid of some missionaries, the party at length reached Tali, but were soon compelled to leave again owing to the Sultan's unfriendliness. By consummate generalship and great presence of mind Lieut. Garnier conducted his party once more across the frontier, where rumours of the death of their chief reached them, causing them intense anxiety. At length a letter from Dr. Joubert confirmed the rumours, and plunged them all into the deepest distress. Finally, in May 1868, they embarked on the great Kiang at Sin-chan-fu, and reached Hankau in the beginning of June, just two years from their departure from Saigon. Here they found once more countrymen of their own, a European settlement, and means of transport to carry them back to their native land. The whole distance over which they travelled between Cratieh, at the head of the Mekong Delta, and Sinchan on the Upper Yangtsé, amounted to 2460 miles, of which about 1650 were performed on foot. To this must be added about 2000 more in excursions and digressions by separate members of the Expedition; and they have surveyed an extent of actual itinerary of over 4000 miles in all, besides an immense number of astronomical determinations.

ECONOMIC SCIENCE AND STATISTICS.

Address by Lord Neaves, *one of the Lords of Session, President of the Section.*

A distinguished predecessor in the occupancy of this chair commenced its business by declaring it to have been the custom that the proceedings of the Section should be opened by an address, and that that address should be a brief one. In complying with the first of these rules, I shall endeavour, if I can, not to forget the second; but the subjects falling within the jurisdiction of the Section are extensive, and compression is always difficult, particularly to one who like myself am rather a novice in the matters of which I am to treat.

Economic science is sometimes spoken of as having a very modern date; but I think that this is an error. More or less the subject has entered into all the codes or systems of law that have been established from the earliest times. Alongside of political philosophy, which may be considered as peculiarly the science of Government, great attention has always been bestowed upon matters which form an important part of political economy, or economic science—such as taxation, trade, commerce, wealth, and population. Those writers also who have presented us with ideal or imaginary States, or Utopias, are full of discussions and speculations of the same kind. The rival 'Republics' of Plato and Aristotle afford abundant illustrations of this statement. It is peculiarly interesting to see this fact brought out so vividly in the admirable introduction to the 'Republic' of Plato, prefixed to that treatise in Professor Jowett's translation of that great philosopher; and if we had a similar translation and exposition of Aristotle's kindred work, which I think we might have from the hand of one of our own Vice-presidents, to whom

we owe so excellent an exposition of the "Ethics," we should see in a remarkable manner how many of the most interesting questions of the present day were considered and dealt with by those two wonderful men according to the varying lights and tendencies which characterized their several minds. It is true that in more recent times a great advance has been made in economic science, and one feature and excellency of that change is the tendency to leave things as much as possible to their spontaneous operation, and to the inherent laws of nature and society; though here again there has latterly been a reaction. It is to the credit of Scotland that she has produced the two greatest leaders in this modern movement—David Hume and Adam Smith—who are still high authorities on the whole subject, and whose principles have been made the basis of much of our recent legislation.

The subject of Statistics is added to the title of this Section as an auxiliary to the main subject of economic science.

Statistics and their Fallacies.

The study of statistics, though not entirely of modern origin, has assumed a special prominence in recent times. Statistics are certainly more of the nature of a means than an end, and their great use and object I take to be to establish, by showing the proportions or averages of results as they actually occur, the existence of certain natural laws possessing the character of absolute or general uniformity. But statistics are liable to hazards, which it is most important to attend to and guard against. It is a common jest that there is nothing so fallacious as figures, except facts; and, as generally happens, this jocular reproach has enough of partial truth in it to preserve it in vitality. Two qualities of mind are employed in statistics of very different kinds—namely, accuracy in observing and recording facts, and wisdom in deducing inferences from them. These two different faculties must act in harmony together; and if they do not do so, fallacious conclusions will inevitably be the result. Let me give some easy and familiar instances of the fallacies that may thus be caused.

In the course of my duties as a judge of the Supreme Criminal Court, I have occasion from time to time to find at circuit towns very light or even altogether empty calendars; and when there is no case to try at all, this is naturally a matter of rejoicing for all concerned, of which the judge has the double benefit in having nothing to do, and in carrying off a pair of white gloves. Latterly, however, I have been led in such cases to make the remark to the local authorities, that a light calendar was not an unequivocal sign of a satisfactory state of things in a district, for that result might arise in two ways—either from no crime being committed in the locality, which is a just subject of congratulation, or from few or no crimes being detected and brought to justice, though many may have been committed, which is a very deplorable condition of affairs. This consideration, I am glad to say, was not called forth by any thing in the state of our criminal police in Scotland, but was suggested and illustrated by the condition of matters in another part of the United Kingdom, where there was no want of crime, but it often led to no prosecutions, from the inability of the law to lay hold of the perpetrators, or to find evidence to prove their guilt. Nay, a deeper fallacy may sometimes lurk under judicial statistics of this kind. It has been said, I fear with truth, that in certain parts of the kingdom the very absence of some delinquencies of a special description is the result of a complete subversion of legal authority. Agrarian crimes are perpetrated there in order to punish or deter those who exercise their legal rights as to land; and when this system of terrorism is complete, the crimes cease to be committed, because the evil organization has attained its object, and does not need to be practically exercised, as no one dares to disobey its lawless mandates. The reign of terror is thus established by paralyzing the exercise of any freedom of action which might incur its penal denunciations. A worse state of society than this can scarcely be imagined, where lawlessness is enthroned and wholly supersedes the law.

Another example of fallacious inference from judicial statistics may be derived from the history of our penal legislation. Until the middle or latter half of last century, the proprietary feelings of the country, and specially, perhaps, of the urban trading classes, incited Parliament to pass severe laws for their protection, which

often affixed to slight violations of property a capital punishment. The number not only of robberies but of thefts, which were then capitally punishable, is almost incredible to us of the present generation; and can now excite only our horror and amazement. I would refer you here to an admirable paper on this subject by Johnson, being No. 114 of the 'Rambler,' which gives an account of the feelings that then prevailed and the system that was followed. The paper, which is most powerfully written, deserves peculiar praise, as being the commencement of those humane and wise efforts for the amelioration of the penal law that were afterwards renewed and brought to a successful issue by the perseverance of Romilly and the practical sagacity of Peel. Dr. Johnson says:—"It has always been the practice, when any particular species of robbery becomes prevalent and common, to endeavour its suppression by capital denunciation. Thus one generation of malefactors is commonly cut off, and their successors are frightened into new expedients. The art of thieving is augmented with greater variety of fraud, and subtlised to higher degrees of dexterity and more occult methods of conveyance. The law then renews the pursuit in the heat of anger, and overtakes the offender again with death. By this practice, capital inflictions are multiplied, and crimes, very different in their degrees of enormity, are equally subjected to the severest punishment that man has the power of exercising upon man."

Now, in this state of things, there is little doubt that after every new application of capital punishment to a crime that did not previously infer it, there might be a diminution of prosecutions on that head, and the public were thus, perhaps, led to think that theft and rapine had in this way received a check. But experience and reflection soon suggested another explanation, which is thus pointed out in the paper I refer to:—"All laws against wickedness are ineffectual unless some will inform and some will prosecute; but till we mitigate the penalties for mere violations of property, information will always be hated and prosecution dreaded. The heart of a good man cannot but recoil at the thought of punishing a slight injury with death, especially when he remembers that the thief might have procured safety by another crime from which he was restrained only by his remaining virtue." In connexion with this last consideration, Dr. Johnson had previously urged that the terror of death "should be reserved as the last resort of authority, as the strongest and most operative of prohibitory sanctions, and placed before the treasure of life to guard from invasion what cannot be restored. To equal robbery with murder, is to reduce murder to robbery, to confound in common minds the gradations of iniquity, and incite the commission of a greater crime to prevent the detection of a less. If only murder were punished by death, very few robbers would stain their hands with blood; but when by the last act of cruelty no new danger is incurred, and greater security may be obtained, upon what principle shall we bid them forbear?" This remarkable paper, written, be it observed, in the year 1751, concludes with the following characteristic sentences:—"This scheme of invigorating the laws by relaxation, and extirpating wickedness by lenity, is so remote from common practice, that I might reasonably fear to expose it to the public, could it be supported only by my own observations. I shall therefore, by ascribing it to the author, Sir Thomas More, endeavour to procure it that attention which I wish always paid to prudence, to justice, and to mercy." We may thus see how mere numerical statistics in such questions may speak an ambiguous language, and that the paucity of prosecutions may be a proof, not of the wisdom, but of the inefficacy of our legislation; for while it is doubtful how far criminals, or at least habitual criminals, are deterred by capital punishment, which they come to look upon as the fortune of war, there is no doubt that undue severity disinclines injured parties from taking steps to bring down on the delinquent what is considered as an exorbitant penalty. I may here, perhaps, suggest a question whether our country of Scotland was not saved from such evils partly by the institution of a public prosecutor, and partly by the anomalous, but convenient power which he possessed of restricting the pains of law, when they were capital, to an arbitrary punishment—a resource which was likely to render juries less unwilling to convict than they might otherwise have been. I should mention that a protest against the severity of the penal laws as to property was uttered by an earlier opponent of the system, though one not so disinterested as Dr. Johnson: I mean the widow of the freebooter

Gilderoy, or whoever it was that wrote the Lament bearing that name. The verse I refer to runs thus, and is expressed in very good "braid Scots" and very fair metre:—

"Wae worth the loons that made the laws
  To hang a man for gear:
To reave of life for sic a cause
  As stealing horse or mear!
Had not their laws been made sae strick
  I ne'er had lost my joy;
Wi' sorrow ne'er had wat my cheek
  For my dear Gilderoy."

There is another matter of a different kind on which the language of statistics is also ambiguous. The relations of the sexes constitute a most important branch of economical science, and in no point is information of more value than where it refers to female purity or to the circumstances affecting marriage. We have now generally in our registers a good enumeration of the legitimate and illegitimate births that occur among us, but I wish to point out some of the hazards or uncertainties by which these are surrounded. In Scotland, as a whole, there is undoubtedly a considerable proportion of births that are illegitimate; but the proportion varies much in different localities. Ten per cent. is not by any means the highest proportion; but let us suppose two districts, A and B, where the proportion is much smaller, say 5 per cent. in each. What does this indicate? It may proceed from a greater degree of moral purity, as fewer examples of unmarried cohabitation will, of course, diminish the number of illegitimate births. But the small proportion of those births may possibly be produced by a totally opposite cause; for it is equally certain that extreme licentiousness of morals, and especially any professional profligacy among women, has a tendency to diminish the number of children born. So that district A, with a small percentage of illegitimate births, may be a very moral district, and district B, with the same small percentage, may be full of prostitutes and other dissolute women, who, from that very character, seldom or never give birth to children at all.

I mention these fallacies in statistical studies, not with the view of discrediting the science, but in order to show the necessity of looking below the surface, and of pausing in our deductions till we are sure that we have all the necessary materials for judging.

The subject I have just touched upon is intimately connected with the habits of a population as to the contracting of marriage. Early marriages have necessarily a tendency to check illicit intercourse, and are often encouraged with that view. The Catholic clergy are supposed to recommend, if not to enforce, such marriages with a view to the moral purity of their flocks. But it ought to be remembered that the remedy involves other evils of its own; and it may be suggested that, if female chastity can only be preserved by the marriage of young persons when little better than children, this is not a very high tribute to the prevalence of good principles, nor a result that is a just subject of pride. I suspect, indeed, that other ecclesiastical bodies besides the Catholics have the same tendency to encourage early marriages. A Presbyterian minister in Ulster told me that in the first marriage which he celebrated in his congregation, the united ages of the parties were under 30, and he baptized a child for them a year afterwards. No great good can come of a system such as that, particularly if it be accompanied, as it often is in Ireland, with a further subdivision of the paternal farm for the support of the young couple. A healthy opinion in a people to discourage early marriages, and at the same time to enforce good moral conduct, is a manifest cause of prosperity; and it is said to explain in a great degree the thriving condition of the Norwegian peasantry. But artificial restraints on marriage, without a high standard of morals, do no good. In Bavaria, it seems, from local and partial interests, various legal checks are imposed upon marriages. But, as has been said, "they do not care to check concubinage; and thus the number of illegitimate births in Munich is nearly as large as that of legitimate."

Deductions from the Registrar's Returns.

In connexion with this subject, I feel called upon to say that I consider our

Registers in Scotland to be, generally speaking, in a most satisfactory state, particularly in the important department of Vital statistics, as to which the reports of the Registrar-General, embodying the reports made to him by Dr. Stark, contain reliable information of the most interesting and important kind. One singular result that seems to have been established by the tables there given is, that at every quinquennial period of life, from 20 years of age up to 85, married men die in Scotland at a much lower rate than unmarried men. Sometimes the difference is very great, particularly between 20 and 45, up to which period it approximates to as high a rate as 2 to 1; but after that, the difference, though less, is still very considerably in favour of the married men. The subject is more complicated as regards women, from obvious causes; though here, too, marriage seems to be the more favoured state. As regards both sexes, the advantage on the side of marriage is easily accounted for up to a certain point. Generally speaking, those who marry are likely as a class to be better lives than those who do not. The unmarried will infallibly include a greater number of sickly or diseased constitutions than the married class. Without professing myself an implicit believer in Darwin, I acknowledge the truth of several of his statements in his 'Descent of Man,' as to what he calls Sexual selection. As a general rule, the attachments that lead to marriage will be prompted by considerations that are intimately connected with health and strength. Good looks, cheerful tempers, and buoyant constitutions are great attractions, and those who are wholly devoid of these, as well as those who are the victims of positive bad health, will often be excluded from having tickets in the matrimonial lottery. No doubt causes occur not unfrequently which disturb these natural tendencies. Some of these causes are allowable or laudable, others are the reverse. In a few cases affection leading to marriage may be inspired by great virtue, or great talent, or high accomplishments, though not associated with health or strength. In other cases, connexions may be formed that are wholly unconnected with love—as where rank, or wealth, or influence may overcome the natural repugnance excited by deformity or disease. Burns, I think it is, that says—

> "Be a lassie ne'er sae black,
>   If she hae the penny siller,
> Set her upon Tintock tap—
>   The wind will blaw a man till her."

Still, as a general rule, both men and women who are married are likely, on an average, to have more health and vitality than those who remain single. As regards the male sex, again, those of them that are of dissolute habits or unsettled and thriftless dispositions, are not so likely to marry as those who are orderly and well-conducted, and in favourable circumstances of life. But after making allowance for these elements, it still appears that the death-rate of married men is at all periods of life lower than that of the unmarried. This can be accounted for only on the footing that marriage is favourable to health, by conducing to regular habits of life, and by giving natural scope to the domestic affections. It cannot be doubted, for instance, that an old man who has a wife to take care of him, will be much better looked after than if he lived alone. It is not necessary in adopting this view to suppose that the married life is to be wholly free from sorrows, cares, and anxieties. Even these are not always prejudicial to health; and we are, perhaps, the better for them when they are well encountered. Neither is it essential that the matrimonial current should always run a smooth course. Most of us, probably, would agree with the view taken by Paley, who, when an old clergyman at an episcopal dinner asserted that he had been married for forty years, but had never had a difference with his wife, observed quietly to the bishop that "it must have been very flat." An occasional ripple will occur in all water, unless it be frozen over, and perhaps after marriage, as well as before it, there may be truth in the maxim, "Amantium iræ amoris redintegratio."

In referring to this matter it has occurred to me to consider whether, if the lower death-rate of married persons is an ascertained fact, this may not partly account for the general success of Life insurance offices when well conducted. It is clear that an office transacting on the usual calculations of mortality, has advantages of various kinds. In particular, its medical examinations, which are a most important part

of its constitution, exclude hazardous lives, except, at least, at extra premiums. The rank of life, probably, of parties effecting insurances may also benefit the office; but if married men are to a certain extent to be considered as selected lives, this also, I should think, must tell in favour of the office, as I presume that, from family reasons, more married men effect insurances than unmarried men.

In general, of course, it is impossible to derive any good result from statistical facts or apparent coincidences except by comparison. A high official person connected with Scotland was summoned before a Committee of the House of Lords to give evidence in connexion with the new Divorce court proposed for England, and was asked whether, in his opinion, the facility of divorce existing in Scotland was unfavourable to the morality of married persons there. The judicious answer was, "I have not sufficient experience of the comparative morality of married persons in different countries to be able to give an opinion on that question."

Matters not yet Reduced to Statistics.

The subjects to which statistics may be extended seem to be innumerable, and new ones are cropping up every day. In the pages of 'Nature' there lately appeared a letter of a somewhat curious kind, which may perhaps engage the attention of our fellow-associate member Mr. Tyler. The suggestion in that letter was that the degree of civilization existing in any country is connected with the quantity of Soap there consumed. The writer gave as a formula the equation of

$$x=\frac{S}{P},$$

x being the amount of civilization inquired for, S being the soap consumed, and P the population consuming it; so that the amount of civilization depended on the proportion of S, the numerator, to P, the denominator. If S is large in proportion to P, then the civilization is great, and *vice versâ*. How the civilization of Scotland in the olden time would come out according to this test I shall not inquire; but if there is any truth in the proposition, it gives additional relevancy and interest to the question which is sometimes vulgarly put by some people to their friends as to how they are provided with that commodity. I have not yet seen any tables framed upon this principle, but I have no doubt that the Registrar-General will keep it in view.

An inquiry of a more serious nature, and indeed peculiarly important and impressive, is connected with one of the most remarkable phenomena in human nature—I mean the occasional appearance in the world of men of great genius. From time to time men have arisen whose mental powers have far transcended the ordinary standard of human intellect, and who have thereby been enabled within the space of a single life, and by the effort of a single mind, to give an impulse to science and discovery which they could not have received through long generations of average mediocrity. Whether this singular boon and blessing to mankind can be traced to any law is a natural but mysterious inquiry. Some persons have considered the production of exceptional genius as quite an insulated fact; and Savage Landor declared that no great man had ever a great son, unless Philip and Alexander of Macedon constituted an exception. Mr. Galton, however, in his interesting work on 'Hereditary Genius,' has endeavoured to prove that genius runs in families, or, at least, that men of genius have generally sprung from a stock where great mental power is conspicuous; and he adheres to the view commonly taken as to the importance of the maternal character and influence in the formation of genius. I do not venture to give any opinion upon Mr. Galton's theory, but his book contains an important collection of facts bearing on the subject, and a great deal of curious collateral speculation. Mr. Galton attributes great power in many ways to the principle of *heredity*, as it seems now to be called. He does not, indeed, go so far as the Irish statist, who, as mentioned by Sidney Smith, announced it as a fact that *sterility was often hereditary*; but he states that comparative infertility is transmitted in families; and adduces as a remarkable example, a fact not generally known, if it be a fact, that in the case, that frequently happens, of Peers marrying heiresses, the family is apt to die out very soon, the heiress being naturally, in the general case, an only child, and bequeathing to her descendants a tendency to pro-

duce small families, which do not afford the usual chance of a numerous supply of descendants. Whatever may be said of some of his other opinions, I hesitate to concur with Mr. Galton in his proposition, that as it is easy "to obtain by careful selection a breed of dogs or horses, gifted with peculiar powers of running or of doing anything else, so it would be quite practicable to produce a highly gifted race of men by judicious marriages during several consecutive generations." I doubt greatly the practicability of such a plan; and suspect there are some elements in human nature that would counteract it. Persons of proud family descent have often a horror of mesalliances; but I scarcely think it would be possible to inspire people of genius with the same *esprit de corps* or desire to wed with those on a par with their own eminence. Men of genius do not seem to me apt to fall in love with women as clever as themselves, and I rather suspect the tendency is to look for some difference of character, an instinct of which it is the object, or at least the result, to keep up the average of talent rather than to multiply the highest forms of mental power. At any rate we may here ask poor Polly's question: "Can love be controlled by advice?" and however we may in other respects agree with Horace's maxim, "Fortes creantur fortibus et bonis," I question whether a high mental stature could be maintained by coupling male and female genius together, or whether the experiment might not fail as signally as it is said sometimes to have done with Frederic William's attempts to breed grenadiers. I strenuously advise, however, that a marriage with a fool of either sex should be always considered as a mesalliance, and I would particularly warn the ladies against such a step, taken sometimes, it is said, in the hope that their sway may in that way be more easily maintained. A fool is as difficult to be governed as a mule, and the couplet, I believe, is strictly true, that says—

"Wise men alone, who long for quiet lives,
Wise men alone are governed by their wives."

Economic Laws.

Leaving the multifarious field of Statistics, and reverting to our leading subject of Economic science, or which may seem a synonymous term, Political economy, it embraces specially the study of those natural laws which have reference to the Wealth of nations. This is perhaps its proper character as a science; but when those laws are ascertained in their natural operation, practical questions arise of great difficulty for the determination of any Government desirous of promoting, not merely the wealth, but the welfare of a nation. How far in particular are those laws to be left to their natural and spontaneous operation? or, how far are they to be modified either by limiting or by supplementing their operation? For example, freedom of trade and freedom of contract are, as a general rule, the best means of promoting activity and prosperity in the departments with they are concerned. But it can scarcely be maintained that this ideal freedom is never to be infringed. I do not merely refer here to the protection which may be afforded to persons under age in reference to their treatment, or to the manner in which they may be employed. In the eye of the law as well as of reason, a contract as to the employment or services of a person in nonage is in reality no contract at all. An infant or minor cannot contract, and any contract that may be made in his name by any guardian, or even by a parent, in every country where law is established, must be subject to revision. A cruel or injurious contract as to a child's labour must be capable of correction and repression, just as any bodily outrage inflicted upon a man would infer punishment and restraint. Even with persons of mature years the general and better opinion seems to be that certain classes of the community require to be protected by restrictions on the freedom of commerce or contract. Long ago this system extensively prevailed, and very high and comprehensive ideas existed as to the paternal duties thus incumbent on Government. Let us take two instances of this kind, which may be placed, to some extent at least, in contrast with each other.

The history of the Usury laws is well known. Originating in a primitive idea that interest upon money was unnatural, those laws kept up prohibitions against the amount of interest that could be stipulated, with a professed view to the protection of needy borrowers against extortionate lenders. It was not till the year

1787 that there issued from the wilds of Russia a voice in defence of Usury, which proved to all thinking men the falsehood and folly of the existing system; but it was still many years before the wise views of Bentham on this subject were carried into practical effect.

The Truck System.

Take, on the other hand, the case of what is called the Truck System. There is nothing in abstract reason to prevent master and servant, employer and workman, from agreeing, if they please, that the remuneration shall consist partly in the supply of food or furnishings. Many contracts for work or service proceed expressly upon that footing, and could scarcely be arranged on any other. But the fraud or unfair proceedings to which the truck system so often leads, the oppressions and exactions often involved in it, the overwhelming power of the masters or their managers in working it, and the helpless condition to which it reduces workmen and their families, are such that public opinion seems so powerfully directed against it, that the laws for repressing it are more likely to be tightened than relaxed. Whether the workmen will ever be so free and independent as to dispense with protection, or whether a healthy and high feeling of self-respect and honour will prevail among masters, so as to place under ban those of their number who use or abuse this system, are matters of which I am incompetent to judge; but I fear that for a long time some restrictions will be maintained. The existing condition of things is most unsatisfactory; for the Act seems to be constantly evaded, and all evasions of statutory regulations are morally, as well as economically, mischievous. The best remedy is, if possible, to diminish the improvidence of workmen; for, in most cases, if the workman has enough in hand to live without advances before pay-day, he is practically independent of his master. Mariners, I may add, seem by common consent to be always treated as children of a larger growth, and protected accordingly. The criterion after all must always be the *majus bonum.*

The Truck system is a term commonly used to denote the arrangement by which, directly or indirectly, workmen are compelled to take payment of their wages, or of advances made to them on their wages, not in money, but in goods furnished from the employers' stores or shops. But the same name has been given to a system that has long prevailed in Shetland, by which the dealings of many classes (tenants, fishermen, and workers of different kinds) are carried on by way of barter, with little or no use of money. This is a different sort of system from the ordinary method of truck between master and servant; and one which, in my humble opinion, is still more difficult to deal with. The *modus operandi* may be generally understood by a few illustrations. The Shetland farmer is, in the ordinary case, possessed of no capital, and seldom pays his rent in money. He is unable probably to support himself by any independent means until his small crop is reaped, or the produce of his farm ready to be realized. He is consequently obliged to seek assistance in the meantime by obtaining advances from some quarter or other. He is also, as a general rule, a fisherman on his own account, but having no capital, he is obliged to run in debt for his boat, or his share of a boat; and again he is obliged to resort to others to support himself and his family until the profits of his fishing can be realized. The employment of fishing is notoriously a precarious one, and introduces into his condition an element of chance and risk that operates powerfully to affect his dealings. It is not easy for a party in such circumstances to obtain advances or furnishings where these can only be accorded to him upon doubtful credit and at considerable hazard. The consequence has been that, for an immemorial period, the Shetlander has been chronically a debtor to others, as fishermen commonly are, and not unnaturally the party with whom he has to deal has come to be the proprietor of the land, or his factor or middleman. What might be done by a good or generous creditor in such circumstances, I shall not attempt to conjecture; but generosity is not a mercantile virtue, and if a dealer tries to make his own profit as great as possible, and still more if he is a greedy and unscrupulous man, the poor Shetlander is in a bad way. The dealer has him greatly in his power, both as to the quality and as to the nominal price of his goods; and no doubt much injustice may be done in this way. Another feature comes frequently into play. The females of the Shetlander's family occupy themselves in knitting

those delightful shawls and articles of hosiery with which we are acquainted, and these the women carry to certain dealers to dispose of; but here it is alleged, truly or falsely, that, by ways and means, these workers are induced almost invariably to take payment in goods consisting in great part of gay cotton prints, showy ribbons, and other articles of female dress or finery, not always well adapted either to their position or to their humid climate. Another favourite commodity for which their worsted work is exchanged is tea; and it is well known that high-priced tea is the great temptation which the Shetland women are unable to resist, tea-totalism in Shetland being often as much of a vice as it is thought a virtue elsewhere. When the dealers with whom the family has to do are all connected with the landlord or the land, the case becomes extremely complicated, and a further cause of mischief arises, as the Shetlander seldom or never has a lease, or will accept of one, and is thus under the constant fear of being ejected if he thwarts the proprietor or his representative in any of his transactions. It thus happens that a Shetland family may be industrious in all its branches—farming and fishing, and knitting to the best of their ability, and yet will be constantly behind hand, dependent upon their superior, and never perhaps handling a pound note from year's end to year's end. The dealers, on the other hand, are said to make large profits, at least at times; but whether on the whole they are great gainers it is not easy to tell, as the state of their transactions has never fully been brought to light. I am far from saying that all, or even the majority, of the landowners are mixed up in these transactions; but the system is so well established that it is difficult to keep free of it. This is certainly not a very good state of things. It has been said that the very boys when they begin to work for wages get no money, but are supplied with clothes, including specially a coat to go to church in, and thus they get very early into the merchant's books, so that perhaps it is not much of an exaggeration to say that a Shetlander is under truck from his cradle to his coffin. Much clamour and complaint have been excited by these pictures, and loud demands are made for stringent and special legislation. It is quite right that full inquiry should be made into the facts; but I confess I have little hope of seeing the evil cured by Act of Parliament. It would be preposterous to enact that no tenant who was starving should be assisted with advances except in money, or that no girl should exchange her woollen manufacture for a cotton print; nor, in like manner, would it be practicable to say that a tenant should not pay his rent in cattle or in fish. The evil lies deeper than this, viz., that the Shetlanders are trying to carry on the business of farming and of fishing without the necessary means. If the steed has to wait for his food till the grass grows he will probably starve; and so will the farmer come to grief if he has not something laid by to live upon between seed-time and harvest. It is the possession or the want of the capital that makes the great difference between master and servant, farmer and labourer. The man who cannot wait till the fruits of his labour or industry are realized, ought naturally to be a servant, and ought to receive wages or support independently of results; but in so doing he must forego the right to claim those profits which are to compensate for risk and delay. If the farmer or fisher insists on going on on his own account without any means—and it is plain that the Shetlander's feelings or habits are adverse to his becoming a servant—it is certain that he must become a borrower, and he will not get aid from any lender without ample remuneration. That remuneration may be got either by charging high interest, or, as they do in Shetland, by making their advances in such a form and manner as will yield them a mercantile profit. This system has been so long established in Shetland, that the people are in a great degree reconciled to it, and its extirpation seems scarcely possible. I think that if I were a resident Shetland proprietor, I would rather let the system go on, but endeavour that it should be so administered as to do justice to both parties, in the hope that by degrees a spirit of independence and fair dealing might grow up. I must say that I am very incredulous of any dealers getting, in this or in any other way, an exorbitant profit in the long run. For if that were the case, competition would be evoked, and one dealer would bid down or bid up the market till it reached a fair rate or return.

Pauperism.

I should regret if this Meeting should pass away without something being done

to bring before us in a precise shape the comparative principles and practical operations of the poor laws in England, Scotland, and Ireland—a subject undoubtedly of great interest and importance. In connexion with the subject of pauperism, one of the most important elements for consideration relates to private charity. It is certain that an enormous sum of money is annually distributed in that way throughout the kingdom, and it is equally certain that the good done bears little proportion to the amount given. It cannot be too much inculcated upon men's minds that the givers of indiscriminate charity are practically to be classed among the most mischievous enemies of the poor. The direct tendency of what they do is to tempt and encourage the poor to become hypocrites and impostors, to paralyze their industry, and to undermine their self-respect and self-reliance. It is false to call such expenditure by the name of charity. A great deal of it doubtless proceeds from feelings of true benevolence; but how much of it is prompted by other motives? The desire to do as others do, the wish to avoid the unpleasant sight of distress, real or apparent, the inability to resist importunity, the superstitious idea that it is a duty to give a portion of our means in the name of alms, without regard to the effect produced, just as the Pharisees were scrupulous to pay tithes down to the lowest article. Protestants are in the habit of reproaching Catholics with the importance they attach to mere good works; but that fault is not confined to Catholics, but is deeply seated in human nature. The false notion of expiating sins, or of propitiating Divine favour by some self-sacrifice that is perhaps easily made, prevails in all sects. A story was current some time ago of a man belonging to a very anti-Catholic sect, who had become rich by very questionable means, and who, when on his death-bed, asked his minister whether, if he gave £10,000 to the church, it would improve his prospects in the other world. The cautious and conciliatory answer was, that it was impossible to guarantee any such matter, but that it seemed an experiment well worth trying. No such liberality, whether in one's life-time or on death-bed, deserves the name of charity. There can be no charity unless there is the desire to do good to the recipient; and there can be no enlightened charity that does not seek to carry out that wish in the right way, by making careful inquiry as to the circumstances in which the boon is bestowed, and the effect which it is likely to have. It is not an easy task to accomplish this object; but I am glad to see that on all sides measures are being taken, by the help of associations and otherwise, to assist benevolent persons in wisely and intelligently carrying out their views. Two great considerations are here to be looked to—the real destitution of the parties to whom charity is given, and the caution that confines it mainly to casual and extraordinary causes of distress, and does not establish any resource on which the poor can rely, so as to dispense with ordinary and necessary prudence on their part.

On Sanitary Measures for Scottish Villages. *By* Colonel Sir J. E. Alexander, *K.C.L.S.*, *F.R.S.E.*

Within the last forty years there has been a gradual improvement in many Scottish villages, which by the absence of attention to the outward and visible signs of cleanliness, exhibited great carelessness in sanitary measures. Manure-heaps are still, no doubt, not far off from the cottages; but it is the business of the sanitary officers to see that they and pigsties are not close to doors or windows. Some of our health officers are firm and do their duty, and insist on attention to sanitary rules; others again wink at irregularities, and favour particular parties to the injury of their neighbours. There is still a vast amount of ignorance both as to the necessity for pure air and water to insure good health to the community.

In visiting the cottages we still see occasionally that fever-chest called a "box-bed," in which at night a father, mother, and two or three children may be found, with the air poisoned by their breath. We still see in many cottages windows built into the wall, and quite incapable of being opened. Landlords should endeavour to remedy this evil, as it costs little to make an arrangement for admitting air through the natural channel—the window. How can we expect to find health

in a room sometimes without a fireplace, with door and window closed, and no current of air through it?

The author described some of the habits of the cottagers, and noted the improvements which are to be observed in the tidiness of their dress, and in other respects. He advocated the promotion of the taste for music, and instruction in the principles of hygiene in village schools.

On some Maxims of Political Economy as applied to the Employment of Women, and the Education of Girls. By Lydia E. Becker.

In regard to employments common to both sexes by which persons gain a livelihood, one rule is of almost universal application, that when men and women are engaged in the same occupation, the remuneration of women is fixed at a lower rate than that of men. In some cases this arises from actual superiority in men as men for the work, in others from the superior advantages in training which are arbitrarily given to men. In the Staffordshire potteries the higher and more elegant branches of the trade, the modelling and painting, are given to men, while women do the rough heavy work. In teaching, where the requirements from men and women are equal, and the capacity of either sex for the work the same, women are paid only about two thirds the salary of men. It is said that, as a matter of fact, a schoolmistress can be had for less money than a schoolmaster, and therefore the law of supply and demand, and the rules of political economy require that she should receive less. But while this rule of political economy is alleged as a reason for keeping down their remuneration, women find that some other rule than that of economic science is brought in to prevent them from having the benefit of the law of supply and demand when that rule would tell in their favour. In order to make it just that women should receive only the market price for their services, there ought, on the other hand, to be an open market for their labour; but women are not allowed to compete for the best paid educational posts. It is arbitrarily assumed that they cannot teach boys, therefore in this country they are shut out from the most profitable part of the teaching profession, although experience proves that women make excellent teachers of boys.

Sometimes it is alleged as a reason for the inequality between men and women's salaries, that it must be assumed that a man has a wife and family to maintain out of his income, and this is usually not the case with a woman. But this reasoning goes beyond the law of supply and demand. In calculating wages, the employer has no right to go beyond the consideration of the quality of the work demanded, and the number of competitors for the post, in the question of what the recipient of the wages means to do with the money, nor to assume that he or she cannot need such and such a sum. Women are arbitrarily shut out from many employments in which they are fully competent to engage. There has been an interposition on the part of University authorities to hinder the supply of women doctors to the demand of women patients. The rule of giving less to women than to men is applied where it cannot be excused under the plea of supply and demand. In the table of conditions under which the Government grant assurance policies and annuities, we find that a man and a woman of like age have to pay a like premium for a life assurance policy, but that if a man and a woman of like age pay a like sum for an immediate life annuity, the woman's annuity will be $7\frac{1}{2}$ per cent. less than that of the man. The introduction of needlework as a compulsory subject in girl's schools acts injuriously on the quality of education to be obtained in them. Boys are allowed to devote their whole school time to intellectual work, while girls are only allowed to exercise their intellectual faculties on the condition that they shall devote a considerable portion of school time to manual labour. The gulf between the intellectual attainments of the sexes is already too wide, and the impulse that is being given on all hand to the education of boys is making it wider every day. In order to accomplish the object of getting the whole people thoroughly educated, the wisest and speediest method would be to bestow the principal share of attention on that part which is confessedly behind, that of the feminine half of the nation. When the standard of education for women shall be brought up to the

level of that for men, the education of both sections of the people will advance faster than has hitherto been possible, and the combined intelligence of women and men, educated and trained to a thoughtful appreciation of the truths unfolded by a study of both natural and economic science, will be able to arrive at a solution of social and political problems which have hitherto baffled the wisest of our legislators.

On Land Tenure. *By* William Botly.

The author introduced the subject by stating that "in treating the question he did so on principles at once tangible and practical," not on those of "The Land Tenure Reform Association," but in such a manner as he believed would materially tend to the interest of the three parties immediately concerned, and as a sequence to the well-being of the country generally. He then gave an account of the many and varied tenures by which land is held in Great Britain, France, Belgium, Prussia, the Colonies, &c., deducing their relative advantages and disadvantages. He then gave a statistical account of the counties &c., proving that leases were the exception not the rule; argued in favour of long leases (with few restrictions), showing as a rule long leases and good farming go together, whilst with few exceptions yearly tenancy and insecurity led to bad farming; gave a tabular statement as to the relative yield of such estates. He also advocated Tenant Right to the extent of compensation for all unexhausted improvements and beneficial outlays, instancing farms where such equitable agreements existed having trebled in value and rental.

After showing the beneficial effect on landlord, tenant, labourer, and the commonwealth, concluded by saying that physical, financial, and political benefits would arise from the general adoption of long leases, with a well-considered tenant-right clause inserted therein.

Educational Hospital Reform: The Scheme of the Edinburgh Merchant Company. *By* Thomas J. Boyd, *F.R.S.E., Master of the Merchant Company.*

The scholastic institutions of the Edinburgh Merchant Company probably form the largest system of schools in Great Britain, and are the only ones yet established under the "Endowed Institutions (Scotland) Act."

The Merchant Company of Edinburgh was incorporated in 1681 by Royal Charter from Charles II. It is in a highly prosperous condition, and upwards of 300 leading merchants, bankers, and traders, in Edinburgh and Leith, are members. Since its institution, it has held a very prominent position in Scotland, and its deliberations and resolutions have not unfrequently had considerable influence on public affairs. There is a widows' fund connected with it, from which the widows of members receive a liberal annuity. The entry-money to the Company varies from about £145 to considerably upwards of £200, the exact amount being determined by the ages of applicants for admission.

The principal administration and patronage of three of the educational hospitals in Edinburgh, viz. George Watson's Hospital, the Merchant Maiden Hospital, and Daniel Stewart's Hospital, were vested in the Company, and to it were also confided the chief management and patronage of James Gillespie's Hospital for the maintenance of aged people, in connexion with which was a Free Primary School for boys. Each of these four Trusts possessed a large hospital building, in which, previous to the recent changes, the foundationers resided, and where those of the first three were also educated; and from the able and economical manner in which their respective funds have been managed, their capital stocks have very largely increased.

(I.) George Watson's Hospital was founded by George Watson, accountant to the Bank of Scotland in Edinburgh. He died in 1723, and bequeathed £12,000 to endow an hospital for the maintenance and education of boys. Those who were qualified for admission were sons and grandsons of merchants, burgesses, and guild brothers, or ministers of Old Church, preference being given to those of the name of Watson and Davidson. The income of this Trust now amounts to about £8000 a year. The number of boys educated and maintained in its hospital building be-

fore the reform was eighty-six. The master, twelve assistants, and treasurer of the Merchant Company, five members of the Town Council, and one of the Established Church Clergy of Edinburgh, constitute the management.

(II.) The Merchant Maiden Hospital was founded in 1695 by the Edinburgh Merchant Company and the widow of James Hair, druggist in Edinburgh, for the maintenance and instruction of girls. The income of the Trust is about £6000 a year. Previous to the changes it had seventy-five foundationers. Those eligible for admission were the daughters or granddaughters of merchant burgesses of Edinburgh, or of ministers thereof and suburbs, or of those who have been governors of, or benefactors to, the hospital. The management is in the hands of five members of the Town Council, the Master, Treasurer, and two Assistants of the Merchant Company, three of the Clergy of the city and suburbs, the Earl of Mar, and nine persons elected by the Merchant Company—in all, twenty-two.

(III.) Daniel Stewart's Hospital was founded by Daniel Stewart, of the Exchequer, who died in 1814, leaving upwards of £13,000, to accumulate for the purpose of building and endowing an hospital for the maintenance and education of boys. Those qualified for admission were sons of honest and industrious parents of Edinburgh and suburbs, including Leith, whose circumstances in life did not enable them suitably to support and educate their children at other schools, preference being given to those of the name of Stewart or Macfarlane. The annual income of this Trust is upwards of £5000, and the number of foundationers was sixty-nine. The Master, Treasurer, and twelve Assistants of the Merchant Company constitute the management.

(IV.) The last of these institutions, James Gillespie's Hospital and Free School, was founded by James Gillespie, of Spylaw, merchant and tobacconist in Edinburgh, who, by his will dated in 1796, destined the greater part of his property to the endowment of a charitable school for boys, and of a hospital for the aliment and maintenance of old men and women. About forty aged foundationers were maintained in the hospital building. The persons qualified for admission were, the servants of the founder, or persons of his name, above the age of 55; persons belonging to Edinburgh and its suburbs above the same age; failing these, persons from Leith, Newhaven, and other parts of Mid-Lothian; whom failing, persons from any part of Scotland at the age of 55. The Free School was opened in 1803, and had about 100 boys. For some time no fees were charged, but subsequently, and until the recent reform, the pupils were made to pay a small sum per month, and this change had the effect of increasing their number, which latterly amounted to about 150. The annual income of the foundation is about £1800. The management is in the hands of the Master, twelve Assistants, and Treasurer of the Merchant Company, five members of the Town Council, and the Ministers of St. Andrew's and St. Stephen's churches.

For upwards of a quarter of a century there has been a growing feeling in Scotland against what is known as the *hospital system*; and, happily, people generally are now coming to believe in the truth of the saying that children should be brought up in families—not in flocks. The education of large numbers of children apart from their parents, relatives, or friends, and without their having almost any intercourse with other persons except the officials of the hospital establishments, was a system unnatural in itself, and not calculated to make them in after life useful members of society. With whatever zeal those who were so brought up might be trained morally and intellectually, many were found, on the completion of their education, to be devoid of that general intelligence which is acquired from intercourse with friends in the home circle; and when they left the hospitals to begin the business of life, they were, as a rule, unable to take their places with others whose scholastic training had not been superior, but which had been carried on under happier circumstances. Altogether, it was felt that, in return for the large sum of money expended upon them, comparatively small benefits were derived; and it was to abolish this state of things that the Scheme was devised.

The Merchant Company had for a long time been desirous of reforming the institutions referred to, and with this view they obtained, about nineteen years ago, Parliamentary authority to admit day-scholars, selected from the privileged classes, to George Watson's Hospital, to be educated gratuitously along with the founda-

tioners. Scarcely, however, had even this small liberty been granted, than they were privately given to understand that the passing of the Bill was considered a mistake, and that no more applications need be made to Parliament for permission to alter the wills of founders. As it seemed, then, only a waste of money to endeavour to obtain additional powers, the Company did not fail to stretch those they had to the utmost extent. In the case of the Merchant Maiden Hospital, they admitted as day-pupils a limited number of girls belonging to the privileged classes; and while they deeply regretted that they could not make a more extended use of their funds, they felt that the blame of this did not lie at their door. In the meantime, however, the cry against the hospital system continued, and the Assistant Royal Commissioners reported that there were large revenues connected with the hospitals in Scotland which did comparatively little educational good. Although the Merchant Company believed that their institutions would bear favourable comparison with similar ones either in Scotland or England, yet it was deemed expedient to endeavour to get their usefulness extended by all possible means. Accordingly, in 1869, on the representations of the Company, the "Endowed Institutions (Scotland) Act" was brought into Parliament, as a Government measure, by the then Lord Advocate (Sir James Moncrieff). It encountered considerable opposition, but the Company having obtained the support of the managers of two or three similar foundations in Scotland in behalf of the measure, it finally passed.

The Act gives power to the Home Secretary to issue a Provisional Order for increasing the usefulness and efficiency, and for extending the benefits of any Endowed Institution in Scotland, on a petition of the Governors thereof; and if the order lie forty days on the tables in both Houses of Parliament without an address being presented, it becomes law.

After the Act was passed, a Scheme for reforming the four institutions had to be prepared. No group of educational hospitals, or even any individual one, had hitherto been efficiently reformed, and there was therefore no plan in operation which could form any guide in the matter. Whatever scheme might be devised, it would of necessity require to give good grounds for believing that it would efficiently and satisfactorily utilize the large funds to be disposed of. Besides, there was this further difficulty, that it had to be framed in a way which would satisfy the Merchant Company and the Governors of the four hospitals on the one hand, and have a fair chance of being accepted by the Home Secretary and Parliament on the other.

In preparing the Scheme, it was specially kept in view that it should be of such a kind as would not be likely to clash with the plans which other hospitals in Edinburgh might contemplate undertaking, so that money might not be squandered in fruitless competition. Particularly, regard was had to keep clear of the work which the Governors of George Heriot's Hospital were accomplishing with their outdoor schools in the education of poor children.

The following is a brief outline of the leading features of the Scheme:—They are (1) the removal of all the foundationers from the four hospital buildings, and providing for their maintenance elsewhere; (2) the converting of these buildings into great day-schools, under a graded system of education, for the instruction of children of the general community, along with the foundationers, on payment of moderate fees; (3) the throwing open of presentations to the foundations for competion amongst the pupils attending the schools; (4) the establishing of bursaries and travelling scholarships for the further prosecution of the studies of such pupils, both male and female; (5) the endowing of a Chair in the University of Edinburgh, to complete the commercial side of education to be given in the schools; and (6) the establishing of one or more industrial schools for the neglected children of the city.

A joint meeting of the four Boards of Governors was called for the purpose of considering the Scheme, at which a resolution generally approving of it was unanimously passed. In order to ascertain the opinions of the directors of similar institutions in and near Edinburgh regarding the matter they were invited to a conference. At this conference the Scheme was very fully considered, and, on the motion of Sir Alexander Grant, the Principal of the University, who is a Governor

of two of the hospitals, a resolution cordially approving of its general scope was unanimously carried.

After the approval of the Scheme by a general meeting of the Merchant Company, separate Schemes or proposed provisional orders based on the general Scheme, and extended as to details, for each of the four hospitals, together with petitions to the Home Secretary, praying that he would sanction their being carried out, were in due course approved of by the Company and Governors. With some slight modifications, the Home Secretary agreed, subject to the approval of the Lord Advocate, which was afterwards given, to issue the Provisional Orders.

The Provisional Orders, lying the required number of days upon the tables in both Houses of Parliament without an address being presented, became law in the end of July last year (1870), just as the schools in Edinburgh were closing for the holidays. It was determined to take measures at once for having the four hospital buildings opened as day-schools in the beginning of the following session in September, and otherwise to proceed in carrying out the Scheme. Towards this end, the first thing to be accomplished was to remove the foundationers from the buildings, so that the work of adapting them for their new purpose might begin. It was decided to have in them three graded schools for boys and two for girls, so that each of the different classes of society for whom they were designed might find in one or other of them an education suited to its own requirements.

The building of James Gillespie's Hospital was accordingly chosen for the lowest grade schools of both boys and girls which it was arranged to establish, Daniel Stewart's and George Watson's for the other two boys' schools, and that of the Merchant Maiden Hospital for the upper girls' school. There would thus be equal to five graded schools in the four buildings—those in Gillespie's and the Merchant Maiden Hospital buildings being the two for girls, and those in Gillespie's, Stewart's, and Watson's the three for boys. The word *hospital*, when used in connexion with education, was so repugnant to the general community that, in so far as the schools were concerned, its use was abandoned, and the names adopted for them were:—"James Gillespie's Schools," "Daniel Stewart's Institution," "George Watson's College-Schools," and "The Edinburgh Educational Institution." For each of these institutions a head-master was appointed, whose emoluments were to consist of a salary, and an additional sum for every pupil who should attend the school over which he was to preside. For the upper girls' school a lady-superintendent was also engaged. These persons were appointed by the Governors, at whose pleasure they were to hold their offices. Each of the head-masters was to be responsible for the efficient working of the school under his charge; and, in order to do them full justice in this respect, they were to appoint and dismiss their own teachers and governesses, the Governors fixing and paying the salaries. The foundationers were to attend the school belonging to the Trust with which they were connected, and children of the general public who passed an examination suitable to their respective ages, and satisfactory to the Governors, were to be admitted to all the schools on payment of moderate fees. In selecting out of the applicants those who were to be admitted, regard was to be had to the merits and attainments of each as tested by the examination. In all the institutions there were to be three departments (an elementary, a junior, and a senior), each of which was to be divided into classes containing a limited number of pupils, grouped according to their attainments, and the whole of the pupils, with the exception of those in Gillespie's schools, were to supply their own class-books.

In the lowest grade schools (James Gillespie's), the course of instruction was designed to include English in all its branches, writing, arithmetic, vocal music, and drill. The boys were also to be taught mechanical drawing, and the girls sewing and knitting. Both male and female teachers were to be employed, and the classes were not to contain more than fifty children. The fees, including the use of school-books, have been fixed at 3*s*., 4*s*., and 5*s*. a quarter for the entire course. In Daniel Stewart's Institution and George Watson's College-Schools for Boys the course of study was to include the English, Latin, Greek, French, and German languages; writing, arithmetic, book-keeping, algebra, mathematics, drawing, vocal music, botany, natural history, natural philosophy, chemistry, drill, gymnastics, fencing, and dancing. There was to be a classical and a modern or

commercial side, and instruction in technical science was to be given in Daniel Stewart's Institution to such pupils as desired it. In both schools male teachers only were to be employed, and the number of pupils in each class was not to exceed a maximum of forty, so that the education of every one of them might be fully attended to. The fees for the whole course have been fixed at from 10*s.* to 30*s.* a quarter. In the upper girls' school ("The Edinburgh Educational Institution") the course of study was to embrace all the branches usually taught in the principal institutions and boarding-schools for young ladies, and to include the English, French, German, and Latin languages; lectures on literature; writing, arithmetic, book-keeping, algebra, mathematics, physical science, drawing, vocal music, instruction on the pianoforte, drill, calisthenics, dancing, and needlework. As in the upper boys' schools, the classes were not to contain more than forty pupils. With the exception of the elementary department, where female teachers only were to be employed, the institution was to be taught altogether by masters, with a governess attached to each class, to be constantly in attendance upon it. The fees for the whole course have been fixed at from 12*s.* 6*d.* to 50*s.* a quarter. In the second quarter of the session, when the numbers were counted, the whole of the 1200 girls in this school were being taught English, arithmetic, vocal music, needlework, and dancing, 1120 writing, 1032 the pianoforte, 850 French, 672 drawing, and 352 German. In all the schools religious instruction was to be given. A "conscience clause" was put in operation. At first, only about ten children took advantage of it, but as the session advanced no exception whatever existed on behalf of even a single pupil.

It will be seen that, for the education to be given in the schools, the fees are very low. The principle upon which they were fixed, as regards the three upper schools, is, that they be sufficient to cover the expense of the *additional teaching* required, without anything being charged as against the rent of the hospital buildings, which were to be turned into day-schools, or for the expense of the teaching staff formerly kept up for the foundationers when the buildings were used for the double purpose of giving board and education, and which was expensive if reckoned at so much a pupil. Take, for illustration, the upper girls' school (the Edinburgh Educational Institution), with its 1200 pupils. Of these, about 70 were foundationers, and 1130 day-scholars. For the latter, the number of teachers and governesses was sufficiently increased, the expense of this new staff being defrayed by the fees which these day-scholars pay, and which amount to between £7000 and £8000 a year. Thus, if there had been no other new expenses consequent upon the changes, the education of these 1130 day-pupils would have been productive of neither gain nor loss to the Trust. But there was the rent of the new houses to pay for, in which some of the foundationers were to reside, and those of them who were to be boarded out in families would cost somewhat more than when they lived in the hospital building. Then money had to be found for the bursaries and fellowships, &c. To meet these new expenses the number of foundationers was partially to be reduced. Gillespie's Schools, being established for the children of the humbler classes on payment of low fees, are, of course, productive of a small annual loss, which is, however, met by the growing income of the foundation.

The money required for the expenses of the new purposes of the Scheme was to be obtained by reducing the number of foundationers of the three educational hospitals. The reduction, which was to be effected as soon as convenient, was as follows, viz. the foundationers of the Merchant Maiden Hospital to be reduced from 75 to 61, those of George Watson's from 86 to 60, and those of Daniel Stewart's from 69 to 40. The preference claims of children who bore particular names were altogether abolished. Great evils arose from the obligation to admit such children to educational hospitals. Their education was too often neglected by their guardians in their earlier years, who thought that there was little use troubling themselves about it, or paying school-fees since they would be sure of getting them into a hospital where everything would be done for them. The consequence was, that these children were generally unfit to be placed in the same class with others of a like age; they required an unusually large amount of labour to be expended upon them, and, as a rule, were a drag upon the whole institution.

In regard to the presentations given over to the general community, it may be proper to notice here that the apparent loss to the privileged classes is more than compensated by the solid advantages given to foundationers, not only by their attending the day-schools while being boarded either with their friends or in the boarding houses of the Governors, but also by the spirit of meritorious emulation from without, which works so beneficially upon them as upon all the other pupils of the institutions. Further, the special identity of foundationers is now lost, and a spirit of merit runs through all. Moreover, neither children nor grandchildren of members of the Merchant Company, except those who were in reduced circumstances, could formerly get benefit from the foundations; but now, under the altered state of things, the schools and all the advantages connected therewith are of course open to them.

The Scheme, as formerly mentioned, contemplated the removal of the whole of the foundationers from the hospital buildings. Of those connected with the three Educational Trusts, it was decided to maintain a portion in boarding-houses, under the superintendence of the Governors, and to board out the remainder with persons of whom they might approve. Accordingly, suitable houses were rented, and the plan as to the foundationers carried out. It was agreed that the aged foundationers of Gillespie's Hospital were to have the option given them of either accepting a pension of £25 a year, or of continuing to be supported at the expense of the Trust, under the protection of the Governors, in a smaller house; with the exception of ten, who were old and frail, they all preferred the pension. For these ten, as well as for others whom the Governors may elect from time to time on vacancies arising, the building formerly used as the Primary School has been fitted up. As to the future, it is of course intended to continue the system of giving outdoor pensions, as well as to maintain the Hospital Home for old people.

An important feature of the Scheme, in addition to providing the general community with a superior education at moderate fees, is to give children of great merit, who attend any one of the schools, a high-class education, without almost any expense to their friends. This feature was introduced not only with the view of stimulating the exertions of all the pupils, but also of enabling children of great ability (even those whose friends were only in circumstances to place them at the lowest grade schools) to turn their intellect to the best account, so that they might be fitted to occupy a high position in life, and possibly render important services to the country. Towards this end there are to be given up for competition amongst the pupils of all the schools a portion of the reduced number of presentations to the foundations. That number is to be not less than a fourth of those of George Watson's and the Merchant Maiden Trusts, and not less than a half of Daniel Stewart's. The ages at which the pupils are to compete for the presentations are, for boys, under 10, 12, and 14 years; for girls, under 12, 14, and 16 years. The successful competitors are to be maintained and educated at the expense of the foundations—boys until they are 16 years of age, when they should be ready for the University, and girls until they are 18. These ages may be afterwards altered if the Governors see fit. Then, in order to enable meritorious pupils further to prosecute their studies, power has been acquired to found twenty-two bursaries of £25 a year, tenable for four years; and eight travelling scholarships of £100 a year, tenable for three years, all of which are to be awarded also by competitive examination. Estimating the value of a presentation at £50 a year, the gross amount of benefits which a pupil may derive are—a presentation for six years =£300; a bursary on leaving the schools of £25 a year for four years =£100; and thereafter a scholarship of £100 a year for three years =£300; making altogether £700. I need scarcely again state that these benefits have the advantage of being open for competition to female pupils as well as male. The Governors have also the power at the end of each session, on the recommendation of the examiners of the schools or head-masters, to give substantial rewards to pupils of distinguished merit; and the plan intended to be adopted in carrying out this part of the Scheme is to present those of them who do not succeed in gaining places on the foundations with school bursaries, equal in value to the amount of their fees for the following session.

In the upper boys' school the education was to branch off at a certain stage into

the two divisions of what are called the Classical and Modern or Commercial sides; and while, of course, there is provision in the Edinburgh University for the completion of the former, there was greatly needed, in the interest of the latter, a Chair of Commercial and Political Economy and Mercantile Law. Under the powers embraced in the Scheme, such a Chair has been endowed and a Professor appointed.

There was yet another sphere of usefulness which it was contemplated to overtake. While power was asked which would enable the Governors so greatly to benefit the general community by the establishing of these schools &c., by means of which meritorious children of the humbler classes could receive an education of the best kind, fitted to advance them in life, and while power was also asked to do something for the University, it was thought right to look with a kindly eye on the very poorest of the community—to include in the Scheme powers for establishing Industrial Schools, to assist in gathering in the neglected boys and girls of the city. The carrying out of this work is under consideration, great difficulty having been experienced in view of the Government Education Bill for Scotland (which was expected to pass this session) containing express provisions for industrial schools, compassing the whole wants of the city by levied rates.

The author then described the favourable reception of the Scheme by the Government, the press, and the public generally.

The advertisements announcing the opening of the day-schools appeared about the end of July last year, and in about a fortnight no fewer than 2600 children had passed the entrance-examination. Shortly afterwards the number which could be accommodated in three of the four buildings was made up, there being, inclusive of about 200 foundationers, 3400 pupils enrolled. The head-masters then, seeing the size of the schools which they were to have, advertised for teachers. The plan of selection which they adopted was, while engaging those whom they thought most suitable, to give a preference to such as would be likely to suffer by the new schools. They could not do more in their interest, without running the risk of sacrificing the efficiency of the schools for the benefit of individuals, however deserving otherwise, and thereby imperilling the success of the entire educational Scheme.

In carrying out a great reform like this, it could not be otherwise but that inconveniences and partial losses to some teachers would occur. There was, however, the satisfaction of knowing that, by the limited number of pupils in each class, an increased number of teachers were employed, and that their salaries were considerably greater than they previously had been. It is understood that, in consequence of this, good teachers in some other schools in Edinburgh have since been better paid than they formerly were.

The schools had only been opened for a few weeks when their success as efficient institutions seemed certain. The large number of pupils enabled their being grouped according to their attainments so thoroughly, that those placed in the same class were all but equal. Their individual teachers therefore, instead of having to give separate instruction, as it were, to children in different stages of progress, of which most classes are composed, when speaking to one pupil were addressing themselves to the capacity of all. Thus the classes had a much greater amount of instruction given them than would have been the case in other circumstances. Again, the large benefits to be obtained by competition at the end of the session had a wonderful effect in stimulating the exertions of both pupils and teachers. The consequence was that rapid progress was made in all the schools. Parents, not slow to observe this, in calling at the institutions, said that since their children attended them, they had worked at their lessons in a way which they had never done before, and expressed themselves satisfied with the schools in the highest degree. Persons interested in education from many parts of the country visited the schools, all of whom, the author believed, were most favourably impressed with what they saw; and applications for the admission of other children became so numerous, that at the end of the first quarter the number on the supernumerary roll was very large.

The Scheme provides that a general examination of the institutions has to be made once a year by examiners appointed for that purpose, who are to report upon

the proficiency of the scholars, and on the position of the schools as regards instruction and discipline. The examination is to be conducted by a person wholly unconnected with the Institutions. The first examination was conducted by Professor W. B. Hodgson, who reports thus regarding the upper girls' Institution:—"Probably there is nowhere to be found so large a school for girls so admirably organized and so efficiently conducted. The large number of pupils, far from causing an excessive number in any one class, actually facilitates the work of classification, and by the multiplication of classes, meets the difficulty of unequal progress in pupils about the same age. Where all deserve commendation, it is hard and perhaps invidious to select. But I may truly say that, while the usual branches of a girl's instruction are vigorously attended to, while English, and what it implies, and French and German, and Music and Drawing, hold each its proper place under zealous and efficient teachers, Arithmetic is taught with unusual care, and there are special classes for senior pupils in Latin, Geometry, and Algebra; and the progress and manifest interest in these subjects fully refute the notion that they are unfit for the study of girls. On the whole the state of this school reflects very high credit on its Principal, Lady Superintendent, and Teachers; and it must do much to raise the standard of women's education throughout the whole country."

Regarding the schools generally, Professor Hodgson states:—"It is altogether an astounding organization, and one is quite overwhelmed by the attempt to estimate its results in even the near future. It is something to have lived to see this sight: it is more to have done aught to bring it about."

Professor Oakeley inspected the Music-classes of the upper girls' schools, but no report from him has yet been received.

The author then described the arrangements made for affording increased accommodation, and which include the opening of another girls' school.

For next session the number of pupils already enrolled in the different schools is somewhat as follows, viz.:—

James Gillespie's Schools for boys and girls (full)	1200
The Edinburgh Educational Institution for girls	1100
George Watson's College-Schools for boys	1000
George Watson's College-Schools for girls (full)	500
Daniel Stewart's Institution for boys	300
Total	4100

or already 700 more pupils than attended the schools last session, while new applications for admission are constantly being received.

From what has been said, it will be seen that the annual income of these four foundations is about £20,800. Before the changes which came into operation last year, they maintained and educated about 230 children, maintained 40 old persons, aided a Primary School containing 150 boys, and employed 23 teachers, who received about £1736 a year. In the beginning of next session they will be maintaining 175 children, and educating probably about 4500, while they will be paying teachers and governesses not less than £18,000 a year. It has been estimated that the annual saving to the public, by the reduced cost of education given in these schools, will be about £30,000. Further, the number of the aged foundationers attached to Gillespie's Trust has already been increased, and it is anticipated that in twelve months its funds will admit of a still greater number being placed on the roll. There will also be funds for the payment of the annual endowment of £450 a year for the new Chair in the University. In a short time the Governors will be in a position to decide whether or not the Scotch Educational Bill of the Government will take up the whole field of Industrial Schools in the city.

In conclusion the author expressed the hope that what the Merchant Company have done in using the funds at their disposal to extend the blessings of education, may be the means of inducing the Governors of similar foundations to endeavour to increase the usefulness and extend the public benefits thereof, and in such a manner as may be supposed would have been commended by the generous founders themselves, had they lived in these our days of progress and reform.

On the Measurement of Man and his Faculties. By SAMUEL BROWN, *F.S.S.*

The science of probability, which in the course of 200 years has been perfected by the great mathematicians of England, Germany, and especially of France, and has rendered such service in astronomical researches, is still in its infancy as regards its application to the problems of political and social economy, which directly concern the growth of civilization, and the physical, moral, and intellectual progress of man. James Bernoulli by its aid proposed to investigate questions of interest in morals and in economic science; but his work was not published till 1713, eight years after his death, and in the meantime his nephew, Nicholas Bernoulli, in an essay in 1709, had treated of such questions as the number of persons living after a certain number of years out of a given number born, of the period of time at the end of which an absent man of whom no tidings have been heard may be considered to be dead, of the value of an annuity on human life, of marine insurance, the probability of testimony, and of the innocence of an accused person. Not to mention the extension of the science in the writings of Condorcet, Laplace, and Poisson to the questions of decisions of legal tribunals, of elections, of the relative force of opinions in the minority of voters, the credibility of history; the Census, tables of mortality, marriage, and insurances, to illusions and mental phenomena, we find in recent years the greatest impulse given to scientific methods of collecting and comparing statistics has been by M. Quetelet, the Director of the Royal Observatory at Bruxelles, President of the Central Statistical Commission of Belgium, and the Perpetual Secretary of the Academy of Sciences. He was one of the early founders of this Section at the Meeting at Cambridge in 1833, and was the originator of the International Statistical Congresses which have been the means of effecting such vast improvements in the collection, publication, and comparison of Government Statistics in every country in Europe.

In the application of scientific methods of observation to study the physical and moral qualities of man, an essential part of the inquiry is as to his growth, and the relative proportion of the various parts of the body at different ages until his complete maturity. The last work of M. Quetelet, entitled "Anthropométrie, ou mesures des différentes facultés de l'homme," recently published, comprises the results of many years of observations, in which, by the assistance of scientific friends, artists and medical men, he has succeeded in collecting sufficient and trustworthy facts to trace the law of growth in every portion of the human body at all periods of life.

The methods formerly employed to ascertain the true proportions which constitute the typical man were not satisfactory. Naturalists did not sufficiently study the averages to discover the laws of their agreement or divergence on certain points; artists selected such types of beauty or strength as suited their special purpose. But if some model of the human race existed the proportions of which were so fixed that any deviations from it in excess or defect could only arise from accidental causes, the observations recorded may be divided into groups at equal intervals, and according to the theory of probability the specific number which ought to be found in each group may be predicted beforehand, with a very near approach to accuracy. The greater the number of observations the more certainly will the observed number in each group agree with the number calculated by the theory. The group which approaches nearest to the mean will be the most numerous, and the other groups will be found to contain numbers, as they differ from the mean in excess or defect, in exact proportion to the coefficients of the terms of the binomial theorem. In accordance with this law *dwarfs* and *giants* cease to be casual monstrosities. If out of a sufficient number of observations, taken in any country, of the number of people measured at regular gradations of height, the dwarfs and giants had been purposely excluded, we ought by means of this law to be able to predict nearly not only the numbers which had been omitted, but their relative statures as compared with the rest of the people.

A remarkable confirmation of this law was given by Mr. E. B. Elliott in the measurement of the height of 25,878 volunteers to the United States Army during the Civil War. The intervals of height were taken at every 25 millimetres. At the mean height, 1·75 metre, the number found by measurement was 4054, or 157

in every 1000, whilst the number calculated by the theory would be 153 in every 1000. At all the other intervals the calculated and estimated numbers in eighteen different groups were almost equally near.

Comparisons are given by M. Quetelet of the measurements of the statues of ancient art, and of those in the rules laid down by the greatest artists or writers on the proportions of man. All the measures tend to establish the fact that the proportions of the human form of the present day are almost identical with those deduced by observation from the most regular statues of Grecian art.

The application of the law is also shown by the close approximation in the observed and calculated numbers of conscripts for France, Belgium for 20 years of observation, and in Italy for those at 21 years of age, as well as by two sets of observations in the United States. In the three former countries the mean height observed was nearly the same; but in the United States it was higher by 6 or 8 centimetres, though this was partly accounted for by the Volunteers there being of a more mature age.

A further example is given in a comparison of the measurements of the circumference of the chests of Scottish and American soldiers, the mean of the former being 40 inches, at which the observed numbers were 188, and the calculated number would be 199 in every 1000; and the mean of the latter was 35 inches, at which the observed number was 204, and the calculated number by theory would be 190 in every 1000. The law applies equally to the weight, strength, and other physical qualities of man.

The extension of this method of observation to the actions of man, which are dependent on the exercise of his free will, indicate in the clearest manner that, however imperceptibly to the casual observer, they follow certain laws which are as regular in their operation as the law of mortality. Thus, in five consecutive quinquennial periods, from 1840 to 1865, the marriages of men at certain groups of ages throughout life, with women at the same or other groups of ages, very slightly differed from the mean of the same groups for the whole period of twenty-five years. The same results may be seen in a still more marked manner in England, by comparing the marriages of men at every group of successive five years of age from under 20 to 85, with women at those groups of ages in the three years 1846, 1847, and 1848 with the three years 1851, 1852, and 1853. The near approximation of the numbers at every age in the two periods is most remarkable, especially if they are subdivided into marriages of bachelors with spinsters or widows, and of widowers with spinsters or widows.

Other statistics illustrating the regularity of action in the free will of man, are those showing the tendency to crime at particular ages, and even the nature of crimes which seem to vary against person, or against property according to the age of the criminal. The object of this paper is to point out the true scientific method of collecting and comparing statistics, to draw attention to the remarkable Tables of M. Quetelet, showing the law of the growth of man, and of the proportions of the various parts of his body at every age of life, and further to urge that the same method of investigation should be extended to the many questions affecting his moral and intellectual faculties which at present are not considered to be within the compass of statistical research.

On the Wellington Reformatory. By Sheriff Cleghorn.

On a proposed Doomsday Book, giving the Value of the Governmental Property as a basis for a sound system of National Finance and Accounts. By F. P. Fellows, *F.S.S.*

The author described the present method of voting and accounting for the national expenditure, amounting to about £70,000,000 yearly, and maintained that there was a great incompleteness in the accounts, which could not be rectified till a Doomsday Book, giving the value of the National Governmental property, was compiled. This must necessarily be the basis of any sound system of national finance and accounts, as, without it, expenditure for capital and for the current pur-

poses of the year must be unavoidably confused, so that a Government may ask for £70,000,000 in any year, and yet spend for the year in question £80,000,000, or only £60,000,000 without the House of Commons or the public being able to detect it. The paper recommended, as a conclusion to this Doomsday Book, the compilation of accounts for each Government department similar to those worked out by the author and Mr. Seely (recommended by Mr. Seely's Committee for adoption), and now being introduced into the Admiralty. It pointed out the great control these accounts gave the Admiralty over its expenditure, and attributed a considerable part of the yearly saving of about £1,500,000 that had been effected in the Navy to the information thus afforded. The author said that with certain exceptions, such as the army and the navy, the only accounts compiled and presented to Parliament were the Estimates and Finance Accounts; and that these finance accounts, *i. e.* "the Estimates," "the Appropriation Accounts," and "Statements of the Savings and Deficiencies on the Grants," as given in the Estimates, were, strictly speaking, merely the banking accounts of the nation, and gave little control over the expenditure, and afforded to the House of Commons no information as to the economical results thereof. For instance, the estimates gave the sums the House of Commons authorized the various departments to expend or draw from the public purse or bank. And the Appropriation Accounts and the "Statement of the Savings and Deficiencies on the grants" gave the actual money expended or drawn from the public purse or bank. He maintained that the public national accounts ought to go much further than this, and to show the application and the results of the money thus withdrawn from the "Bank," and urged, from the illustrations given as to the Admiralty accounts and expenditure, the great results that might be expected therefrom. What, it was asked, would be thought of a great railway or other company whose only account presented to its shareholders was its bankers' book—which had no capital account, no account of the value of its plant, buildings, machinery, rolling stock, stores, &c.—which mixed together its current and capital account (as it must necessarily do under such circumstances), and what would be the result of such a system of management, or, rather, want of management? Any man of business would at once say that there must necessarily be very great waste, if not eventual ruin to the company. Yet, was the Government in a different position in this matter, and could we expect that these evils did not exist? The answer surely could scarcely be the affirmative. The paper concluded by recommending the appointment of a Royal Commission to inquire into and carry out this stock-taking and valuation on one uniform principle for all departments, so that a Doomsday Book might be compiled as the starting-point for a system of finance and accounts similar to that introduced into the Admiralty, by which the Government and the House of Commons would be enabled to have the most effective control over our great annual expenditure. The author also incidentally referred to the ancient Doomsday Book of England, as being the greatest achievement of the Conqueror, and saw no reason why it should not be recompiled on an extended basis.

Political Economy, Pauperism, the Labour Question, and the Liquor Traffic. *By* WILLIAM HOYLE.

On the present state of Education in India, and its bearings on the question of Social Science. *By* A. JYRAM-ROW.

On Naval Efficiency and Dockyard Economy. *By* CHARLES LAMPORT.

On the Edinburgh Industrial Home for Fallen Women, Alnwick-Hill, near Liberton. *By* W. M'BEAN.

This Institution was established in 1856 for the restoration of young women willing to return to the paths of virtue. It was formed on the principle of provid-

ing for them a small home, whose arrangements might be more of the nature of a family than larger institutions can possibly be.

It is situated about two miles from Edinburgh, in an airy and healthy locality, as a proof of which sickness of any kind has scarcely, if ever, been experienced amongst its inmates; the usual number of them is about 30, although two or three more could be accommodated.

The superintendents are a matron, assistant-matron, sewing-mistress, and two laundresses, and the chief employment of the women is washing and laundry work, with a little needlework, instruction in needlework being regularly given by the sewing-mistress. Regular instruction is also given in reading, writing, and arithmetic, with household work and religious knowledge.

The Home is always open for the reception of inmates; and it is chiefly through the missionaries, whose work it is to endeavour to reclaim the fallen, that inmates are received.

After being a year in the Home, situations are provided for the girls, and an outfit given to them; and, as far as possible, an oversight is kept of them after they leave the Home. The Committee endeavour as much as possible to send the girls to situations at a distance from their former haunts, and have on different occasions procured situations and sent several of them to Canada, &c.

The management of the Home is vested in two Committees of Ladies and Gentlemen appointed by the subscribers, but the *general* management is vested in the Gentlemen's Committee, who have the control of the funds.

The property of the Home was purchased by the Committee four years ago, at the price of £630; and they have since expended, in making repairs, alterations, and additions to it, so as to fit it more completely for the purposes of a Home, close upon £900, the whole of which money the Committee have been enabled to pay through extra subscriptions, &c., so that now there is no debt remaining upon it.

	£	s.	d.
The annual cost of maintenance of the Home in 1870, as per detailed accounts published in the Annual Report for that year, was	£941	11	5
(which included £185 4*s*. 4*d*., the expenditure connected with carrying on the washing work), whereof there was received from the work of the inmates in washing, &c.	601	13	4
The balance of	£339	18	1

being provided by public subscriptions, &c.

In connexion with this, it is right to state that all the water required for washing, except the rain-water from the roofs, has to be carted from a burn about a quarter of a mile distant from the Home.

In the eleven years from 1860 to 1870, both inclusive, on an average thirty-two young women have annually left the Home for situations, received back by friends, &c.

On the Mode for Assessing for the Poor-Rates. *By* JAMES MEIKLE, *F.S.S.*

On the Administration of the Poor Law. *By* W. A. PETERKIN, *General Superintendent of Poor (Scotland).*

It was the wish of the entire community that no one should die of actual starvation, and therefore all plans for the distribution of funds raised for the relief of the poor were based on the minimum necessary to maintain life. This was the absolute requirement. The Poor Law of Scotland required "needful sustentation." The interpretation of that term was left to the judgment of local administrations, and there were 885 separate bodies, each acting on its own responsibility. Their decisions were subject, on complaint, to the review of a central authority, instituted by Parliament. Uniformity, under such circumstances, was hopeless, and if practicable, would not be desirable. There was no point to which attention required more to be given than to the necessity of each case combining in itself *destitution* and *disability*. The question of disability was practically more easily

determined than that of destitution, and on that point there was the greatest diversity of opinion amongst all classes. The chief advantage to be gained from the expedient of a poor-house was, that it enabled a local board to administer the rates more satisfactorily to themselves and to the public, by checking in a rough kind of way attempts to impose, and more economically in cases where lodging, nursing, and clothing were required. After giving some statistics and results relating to the cost of pauperism and to illegitimacy, the author referred to the education of pauper children, and said whether local boards could do more for the education of such children than they did, by making attendance at school a condition of relief to the parent, was deserving of consideration; but the supineness of pauper parents as to the education of their children was well known, and it must be borne in mind that the elder children were frequently material aids in the family struggle for existence. Having made reference to the improved condition of the paupers compared with that of fifty years ago, and to the provision for medical aid, costing each parish on an average £40 per annum, he gave some information as to Shetland. In Scotland outdoor relief was the rule; for twelve who received relief at their own homes, only one would be relieved at the poor-house. He concluded by stating that it was an advantage of the Scotch system of Poor-Law administration that every recipient of relief was personally known to and visited by local responsible officers, controlled by 885 separate boards, representing all interests; and that it was of the utmost importance to all that these local boards should be constituted so as to secure an impartial, intelligent, and humane administration.

On the Illegitimacy of Banffshire. By GEORGE SETON, *Advocate, M.A. Oxon., Secretary in the General Registry Office of Births, &c. (Scotland).*

Prefatory Note.—"Since I undertook to read the following paper, which relates to the four years ending 1861, I have not had time to examine in detail the Banffshire Birth Registers applicable to a later period; but I have made such an investigation as to satisfy myself that a collation of the books pertaining to the four years ending 1869 (the latest available records) would establish strikingly similar results. This will appear from the tabular statements contained in a supplementary appendix, to which I shall afterwards refer."

This paper gave elaborate details regarding the illegitimacy of Banffshire during the four years ending 1861, and embraced a supplementary appendix relative to the four years ending 1869.

It showed, *inter alia*—

(1) That the number of illegitimate births recorded in the 8 divisions, 33 counties, and 1020 registration districts of Scotland has been published in the quarterly returns of the Registrar-General since the year 1857.

(2) That during the four years ending 1861, the north-eastern division of the country, embracing the counties of Nairn, Elgin, Banff, Aberdeen, and Kincardine, furnished the *largest* proportion of illegitimate births; while the northern division, embracing the counties of Shetland, Orkney, Caithness, and Sutherland, exhibited the *smallest* proportion, the maximum average being 14·7, and the minimum 5·3 per cent.

(3) That of the counties, during the four years in question, Banff took the highest, or rather the *lowest* place in respect of illegitimacy, showing an average of very nearly 16 per cent., the ratio for Scotland generally being 9 per cent., while that of certain other northern counties was only $3\frac{1}{2}$ per cent.*

The county of Banff embraces twenty-six registration districts, with a population of 56,020 at the Census of 1861, during which and the three preceding years, 7517 births were registered, of which 1189 were illegitimate; in other words, about *one in every six* of the children recorded was born out of wedlock. "In the case of 389 of these illegitimate children, or nearly a third of the whole, the paternity was acknowledged at registration (17 & 18 Vict. c. 80, § 35); in sixty-four

* In 1868 Kirkcudbright was slightly above Banff in respect to illegitimacy, showing 17·5 against 17·3 per cent.; while in 1867, Wigtown was 17·9, Kirkcudbright 15·7, Aberdeen and Kincardine each 14·9, and Dumfries and Banff each 14·5 per cent.

instances the paternity has been subsequently found by Decree of Court, and recorded in terms of the Statute (*Ibid.*); and in twenty-eight cases the children have been legitimated by the subsequent marriage of their parents, such alteration of status being also duly registered (*Ibid.* § 36). In a few instances, the judicial findings relate to children whose paternity was acknowledged at registration, from which it would appear that, notwithstanding the reputed father's adhibition of his signature to the register, the mother is occasionally induced to raise an action against him.

"The mothers of no fewer than 571 of the 1189 illegitimate children (very nearly *one-half*) are registered as being *domestic servants*, 216 as *farm servants*, 22 as *milliners* or *dressmakers*, and 36 as *washerwomen*, *hawkers*, and other miscellaneous avocations; while in the case of 344, or more than a third of the whole, the occupation is not specified.* In several cases the mothers appear to have been *widows*, and, in a few rare instances, *married women* living apart from their husbands.

"From notes by the District Examiner, it appears that the mother of one of the illegitimate children registered at Keith in 1860 is a pauper, and has given birth to *five* illegitimate children; while the mother of one of those registered at Rothiemay, in the same year, is living idle at home, and has given birth to *four* illegitimate children."

Very considerable differences in respect to the amount of illegitimacy present themselves in the different districts, the maximum rate being upwards of 25 per cent., and the minimum as low as 6 or 7 per cent. As a rule, the *sea-board* parishes have a lower percentage of illegitimacy than the inland ones. Neither the excess of females over males, nor the comparative number of houses and windowed rooms, as ascertained at the Census, appear to afford any satisfactory solution of the differences in question. But with regard to the county generally, the comparative paucity of marriages may, perhaps, have something to do with the large amount of illegitimacy.

The paper concluded as follows:—"In a paper which I published in the year 1860, I ventured to suggest a variety of causes as accounting for the illegitimacy of Scotland generally. In the present paper, however, it will be observed that I have almost entirely confined my remarks to a statement of *facts*, from which I incline to think that no very satisfactory deductions can be drawn, in the absence of such detailed information as could only be obtained from a carefully conducted *local* inquiry.

"Even the best districts in Scotland have room for improvement in the matter in question, and here, in the metropolitan county, we have not much to boast of. I freely acknowledge the tendency which prompts us to shut our eyes on our own shortcomings, and to call attention to those of our neighbours; but on the present occasion, I think it will be admitted that the great and continued preeminence of Banffshire in the matter of illegitimacy is a sufficient warrant for my having selected that county as the subject of my remarks."

The paper was accompanied by several tabular appendices, and also by a series of extracts bearing upon the subject from the notes appended by the Registrars to their quarterly returns.

On the Expediency of recording Still-Births. By George Seton, *Advocate, M.A. Oxon., Secretary in the General Registry Office of Births, &c. (Scotland).*

This paper mentioned that, while these births are recorded in France and some other continental nations, they are not registered either in England or Scotland.

It showed, *inter alia*—

That the statistics of the subject are very imperfect.

That under the old and unsatisfactory system of registration in Scotland, a considerable number of still-births appear to have found their way into the parochial records.

That, estimating the still-births in Scotland at $4\frac{1}{2}$ per cent. of the total births, their present annual number would amount to upwards of 5000.

* A more general registration of the occupation of mothers of illegitimate children is now effected in Banffshire and the other counties of Scotland.

That the still-births in Glasgow during the three years ending 1852 were calculated by the late Dr. Strang to have amounted to 1 in 12, or upwards of 8 per cent.*

That in France their proportion amounts to between 4 and $4\frac{1}{2}$ per cent., and in Paris to about $7\frac{1}{2}$ per cent.

That the ordinary proportion among legitimate children is reckoned to be from 1 in 18, to 1 in 20 of all births, and among illegitimate children three times greater.

That many more males are still-born than females, viz. 140 to 100, and that still-births are more frequent in first than in subsequent pregnancies.

The paper also referred to the difficulty of defining the term "still-birth;" to the opinion of medical practitioners that the registration of still-births ought to be confined to children born "Viable," or with a capacity to live; to the Memorial addressed to the Registrar-General of Scotland by the Royal College of Physicians, Edinburgh, in 1858, in favour of the registration of still-births; and to the supposed prejudice in the upper and middle ranks of society against such registration.

The paper concluded with the following statement:—

"Prejudice or no prejudice, the question to be decided is simply this:—Is it expedient that these births should be registered? While I wish to speak with great deference on a subject respecting which a lawyer is probably not so well qualified as a medical practitioner to express an opinion, and notwithstanding the very decided views to the contrary of my esteemed friend the Registrar-General of England†, I have no hesitation in saying that I have long thought that the proposal of the College of Physicians should be carried into effect as a matter of public policy.

"In his able pamphlet on 'The Law of the Coroner, and on Medical Evidence in the Preliminary Investigation of Criminal Cases,' published in 1855, Dr. Craig, of Ratho, says, 'Another apparent step in advance is an enactment in the New Scotch Registration Bill, which came into full operation on the 1st of January, 1855, where in cases of new-born children exposed or found dead, or in cases of persons found dead, a report is to be sent to the Procurator Fiscal, who, 'in case of a Precognition,' is to report to the Registrar before he can enter the case in the register. The birth and burial, however, of still-born children are not to be registered; and thus every facility is afforded for concealment of pregnancy, and for the crime of child murder.'

"In the interests of medical science, moreover, I think it cannot be doubted that the births in question ought to be duly recorded; and now that we have in each of the three portions of the United Kingdom a national system of registration, more or less perfect, the facility of doing so is very largely increased. It is no doubt desirable that a uniform procedure should be observed in the three kingdoms. Already, however, in various important respects, the three systems of registration materially differ; and, accordingly, in the matter in question, it might perhaps be worth while to make the experiment, in the first instance, in the comparatively small sphere of North Britain, leaving England and Ireland to follow, if the experiment should prove a success. Whether or not fresh legislation would be necessary is, I think, open to question. Speaking generally, it appears to me that the registration of still-births is not excluded in the existing statute. Were it otherwise, the regulation relative to the non-registration of still-births would be altogether unnecessary. If, however, the *form* of registration to which I shall presently allude were to be thought expedient, it would probably require the intervention of the Legislature, in the shape of a short supplementary Act.

"As to the mode of practically carrying out the registration of still-births, I am quite prepared to offer a few suggestions. On the assumption that the medical faculty are agreed upon what ought to be regarded as a still-birth, and that it is found feasible to give intelligible instructions upon the subject to the Registrars—upwards of 1000 in number—the first point to be determined is, *the register in which the entries ought to be made*. As I have already stated, the practice in

* Probably too high an estimate.

† See printed paper, dated 6th July, 1869, entitled 'Remarks submitted to the Consideration of the Royal Sanitary Commission by the Registrar-General of England and Wales.'

France is to record still-births in the *death* register, and this course, I apprehend, is approved of by some medical practitioners and others in our own country. But I venture to recommend a different plan.

"It will perhaps be alleged that the events in question must be regarded as either births or deaths, and registered accordingly; *i. e.* either in the birth or in the death register. If the question is to be thus limited, I should incline to prefer the *birth* to the death register, inasmuch as a still-birth cannot be scientifically regarded as a true death; and is, indeed, more of a birth than a death. But it does not appear to follow that still-births should find their way into either the birth or the death register. For many reasons, a *separate register*, specially prepared for the purpose, would be the best arrangement—to be transmitted from time to time to the General Registry Office as its pages are filled, and not *annually* as in the case of the duplicate registers of births, deaths, and marriages. It appears to be quite unnecessary that such register should be kept *in duplicate*; and at the end of every quarter the number of still-births would be reported by the Registrar in his return of births, deaths, and marriages. As to the *form* of the register, I would propose that it should embrace the following particulars:—

"1. Number of the entry.

"2. Sex of child.

"3. Date and place of birth.

"4. Age of child in months and days, from date of conception.

"5. Number of the mother's pregnancy, whether first, second, &c., and whether she has had any previous still-born children.

"6. Names, ages, and designations of the parents, and the date of their marriage.

"7. Signature of the informant.

"8. Date of registration and signature of Registrar.

"As to the *age* of the child, probably considerable difficulty would be experienced in ascertaining this particular. The precise period of conception, and consequently of gestation, cannot be determined by the date of intercourse, and the real duration of pregnancy is, of course, the interval between conception and parturition. In most cases, however, a sufficiently near approximation to the truth would probably be attained.

"As to the party who should sign the register as informant, this might be the duty of the medical practitioner or other professional person in attendance; and where no such person was in attendance, the nearest female relative of the mother, being of full age, present at the birth. Another course would be for the medical attendant to transmit to the Registrar, as in the case of a death, on a form supplied for the purpose, a certificate relative to the still-birth, the event being recorded under the provisions of the statute applicable to births generally (17 & 18 Vict. c. 80, § 27). In lieu of the extract furnished to the informant of a living birth, in terms of the 37th section of the Registration Act, the Registrar should be required to give a burial certificate, analogous to that furnished to the informant of a death (*Ibid.* § 44). It is to be feared that under the existing state of affairs, many still-born children are interred not in cemeteries, but in back greens, water-holes, quarries, and such like places, being treated as brute-beasts and not as human beings.

"The subject appears to be a very important one, and I humbly commend the suggestions which I have ventured to offer to the favourable consideration of statists, philanthropists, and the medical profession."

On certain Cases of Questioned Legitimacy under the Operation of the Scottish Registration Act (17 *&* 18 *Vict. c.* 80). *By* George Seton, *Advocate, M.A. Oxon., Secretary in the General Registry Office of Births, &c.* (*Scotland*).

"It is a wise father that knows his own child."—(*Merchant of Venice.*)

This paper had reference to the subject of adulterine bastardy. After alluding to the well-known legal presumption which assigns the *status* of legitimacy to a

child born in wedlock (*"pater est quem nuptiæ demonstrant"*), to the circumstances under which the presumption may be overcome, and to the statements of Stair and Erskine upon the subject, the author said:—

"The history of the law of legitimacy is fully detailed by Sir Harris Nicolas, in his work on the 'Law of Adulterine Bastardy;' while the present state of the law is set forth in the works of several well-known authors, including the treatise on the 'Evidence of Succession,' by Mr. Hubback (p. 393 *et seq.*), and the 'Law of Evidence in Scotland,' by Mr. Gillespie Dickson (vol. i. p. 190 *et seq.*).

"The *usual* ground on which the presumption of legitimacy is overcome is the non-access of the husband within the period of gestation. Actual proof of such non-access is all that is now required both in England and Scotland; in other words, it is no longer necessary to establish the physical impossibility of the husband's access, by proving the intervention of the '*quatuor maria.*' According to Mr. Hubback, the early writers (including Bracton and Fleta) recognize no such doctrine as that of the *quatuor maria*; and, accordingly, he asserts that 'the law as now settled in its repudiation of this doctrine, is in conformity with the most ancient authorities.' Even Lord Eldon remarked that the law had been scrupulous about legitimacy, *to the extent of disturbing the rules of reason.*

"A somewhat difficult question occasionally arises in connexion with the legal presumption of legitimacy, under the operation of the Act relative to the Registration of Births, Deaths, and Marriages in Scotland (17 & 18 Vict. c. 80). The form in which births require to be recorded is prescribed in Schedule (A) annexed to that statute. The first column of the register embraces the 'Name and Surname' of the child, and the fourth column the 'Name, surname, and rank or profession of the father,' the 'Name and maiden surname of the mother,' and the 'Date and place of marriage.'

"These latter particulars, of course, only apply to the case of legitimate children, the entries applicable to illegitimate births being modified according to circumstances, and the word 'illegitimate' being entered under the child's name in the first column of the register.

"In the case of a *legitimate* birth, the primary informant is one or other of the child's parents, whom failing (in consequence of death, illness, or inability) certain other specified persons. Such parent or other informant is required within twenty-one days after the birth, and under a penalty of twenty shillings, 'to attend personally and give information to the Registrar of the parish or district in which the birth occurred, *to the best of his or her knowledge and belief*, of the several particulars required to be registered touching such birth, and to sign the register in the presence of the Registrar.' As a general rule, the Registrar (whose duties are, of course, purely *ministerial*) experiences no difficulty in recording the births reported to him either as legitimate or illegitimate, according to the statement of the informant. Sometimes, however, a doubtful case presents itself, usually under the following circumstances. A married woman attends at the Office of the Registrar, and informs him that she has given birth to a child, of which, however, she solemnly declares that her husband is *not* the father, adding that she has not had any intercourse with him for a long period, perhaps two or three years; at any rate for upwards of nine or ten months prior to the birth of the child. It may be that, during that time, the husband has been living at a distance from his wife, if not residing out of the kingdom; and possibly the paternity may be acknowledged by the paramour. She makes this statement, in the words of the statute already referred to, 'to the best of her knowledge and belief.' Under such circumstances, would the Registrar be entitled, in virtue of the legal presumption, to disregard the statement of the mother, to record the child as legitimate, and to insist on the mother signing the relative entry as informant? In other words, how are we to reconcile the conflict between the legal presumption in favour of the child's legitimacy with the mother's deliberate assertion to the contrary? The ordinary practice of the Registrar General is to send a printed schedule to the Registrar who reports a birth occurring under such circumstances, of which the following is a copy:—

"INFORMATION to be supplied before the REGISTRATION of the BIRTH of the alleged ILLEGITIMATE CHILD of a MARRIED WOMAN.

1. Date of Birth . . . .
2. Christian and Maiden Name of Mother
3. Name and Designation of her Husband
4. Date and Place of their Marriage . .
5. Where did they respectively reside before Marriage? . . . .
6. Are they still residing together? If not, when did they cease to do so?
7. Where have they respectively resided since that date? . . . .
8. Have they had any personal communication since the date of their ceasing to reside together, and if so, when and where? . . . .
9. Does the Husband concur with the Child's Mother in her statement as to its illegitimacy? . . . . . .
10. Is the Paternity of the Child to be acknowledged by any other Person, in terms of the 35th Section of the original Registration Act? If so, state his Name and Designation . . . . .

I HEREBY CERTIFY that the above Information has been supplied to me, as Registrar of the Parish (or District) of______________________________, in which the Birth occurred, by*______________________________

____

____

______________________________*Registrar.*

*Date*______________________________

"The directions as to the form of the relative entry depend, of course, upon the answers supplied; but in the majority of the cases submitted for consideration, where the statement clearly indicates the impossibility of the husband being the father, the child is described, in the first column of the Register, by its mother's maiden and married surnames alternately, without the addition of the word 'illegitimate,' while in column four, the name of the husband, and the date and place of marriage are omitted, and the mother thus described:—'Mary Brown, wife of David Wilson, shoemaker, who she (the informant) declares is not the father of the child, and further that she has not seen her husband for upwards of (say) two years.' Such an entry, no doubt, affords *prima facie* evidence of the child's illegitimacy, and at a distant period it would probably be somewhat difficult to overcome the presumption. On the other hand, however, the circumstantial statement in column 4 distinctly shows that the child was born in wedlock, its alleged illegitimacy being registered on the information of its own mother; and such information being tendered 'to the best of her knowledge and belief.' If, however, the circumstances are such as to indicate opportunity of access to the husband, or otherwise suggest a presumption in favour of the child's legitimacy, the Registrar is instructed to record the birth as *legitimate* in the ordinary way, even in the face of the mother's assertion to the contrary; and if the husband, or any other interested party, should feel aggrieved by the form of the entry, he is, of course, entitled to take steps for its correction, in terms of the statutory provisions."

* As a general rule, most of the information will be furnished by the child's mother.

On Indian Statistics and Official Reports. *By* Dr. George Smith.

The eight years' administration of the Marquis of Dalhousie, which closed in 1856, was the beginning of intellectual progress in British India. On the conclusion of his splendid series of conquests, and even, to some extent, during their continuance, that distinguished Governor-General set in motion all those reforms which are involved in the railway, the telegraph, the anna or three-halfpenny postage, primary schools supported by a local cess, the Universities and the higher education, such scientific and political expeditions as Colonel Yule's Mission to Ava, the Geological Survey, and such enlightened legislation as the Acts establishing religious and civil toleration, and permitting the marriage of Hindoo widows. During his administration, when reviewing the Charter of the East India Company for the last time, Parliament directed, in 1853, that Reports of the moral and material progress in India should be submitted to it every year. Each Province and each Department has since published an annual report, the whole numbering from eight to twelve.

Led by professional duties to study these reports, and frequently to criticise them, the author was struck by the absence of uniformity and the meagreness of their statistical and economic information. The discussions caused by the Mutiny of 1857 had shown England the need of accurate information regarding India, and the annual Budgets, first introduced by the lamented James Wilson in 1859, had convinced the Government of India of the necessity for statistical information as the basis of financial and political action. Still no reform was attempted till, in 1863, the author submitted to Mr. S. Laing, then Indian Finance Minister, a memorial and a plan on the subject. The author adapted to India the scientific scheme of statistics, published by the International Statistical Congress, which had sat not long before, and recommended the appointment of a permanent committee of officials and non-officials to advise Government on statistical questions. An attempt had previously been made to establish a Statistical Society independently of Government, but that had failed. On Mr. Laing's advice Lord Elgin was pleased to adopt the suggestions, and to appoint what has since been known as the Calcutta Statistical Committee to carry them out.

That Committee, working vigorously at first, divided the whole field among small subcommittees. Mr. Bullen, a well-known merchant of Calcutta, adapted the English Board of Trade tables, so that the Financial Department is now able to publish detailed trade returns from the most distant parts of India every month, and only a few weeks after the close of the period to which they refer. An annual volume is also published. The difficult and complicated subject of the statistics of revenue and expenditure was referred to Mr. R. H. Hollingbery, Assistant-Secretary of the Financial Department, so that that department now publishes annually an invaluable series of three folio volumes, showing the past and present statistics of Indian finance in great detail.

The subject of administrative statistics, other than those of trade and finance, was referred to the Hon. Mr. George Campbell, now the able Lieutenant-Governor of Bengal, and to the author. The committee were pleased to adopt the author's plan, adapted from that of the Statistical Congress, which, however, did not provide for judicial statistics. Mr. Campbell, then a Judge of the Bengal High Court, prepared an admirable series of tables for that department, but the Government of India was constrained to appoint a special committee to deal with the courts of the other Provinces as well as of Bengal. The result is that nothing satisfactory has yet been done for judicial statistics, and no reliable uniform generalization can be made regarding litigation, crime, and police in India. In all other respects, however, the statistical forms seem to be perfect. The administrative tables were referred to the Provincial Governments, and, after undergoing searching and sometimes hostile criticism, because they seemed to interfere with local arrangements and to demand an establishment of clerks, they were finally approved of by the Government of India and the Secretary of State in 1867. That is, each of the ten Provinces which send in annual administration reports, was ordered to report on the basis of these uniform and scientific tables. Since 1867–68 all have obeyed, except the three most important—Bengal proper, Madras and Bombay. The first,

owing to the perpetual settlement of its land revenue and the absence of a link of officials between our civilians and the people, has always been statistically unsatisfactory; but we may depend on Mr. Campbell introducing the reform there also, so far as possible. No countries in the world possess such rich statistical material, which could be made easily available, as Madras and Bombay. But the Reports of the latter are the worst in India. It is to be hoped that the Government of India will see that its orders are carried out so as to work these Provinces into the uniform statistical system. That system is as follows in its main heads:—(A) Statistics of Physical, Political, and Fiscal Geography. (B) Statistics of Protection. (C) Statistics of Production and Distribution. (D) Statistics of Instruction. (E) Statistics of Life. The tables are meant to include all the 153 Feudatory States; but except in those cases where a minority has put the State under direct British management, the Chiefs as a rule passively resist all attempts to obtain statistical information regarding their estates and revenues.

Still the reform thus wrought by the Calcutta Statistical Committee has been immense. To say nothing of the elaborate periodical statistics of trade and finance, there are published in India every year, about August, some ten volumes on the ten Provinces of India, and seven of these volumes contain uniform scientific tables. It has thus been possible, during the last three years, to obtain an almost complete picture of the progress and condition of the 212 millions of Hindoos, Mussulmans, Boodhists, Christians, Non-Aryans, Parsees and Jews whom we rule, and for whom England is responsible, in Southern Asia.

The greatest statistical want of India is now a uniform census of the whole population. Until recently, as still in the three great Provinces of Bengal, Madras and Bombay, the number of the population was arrived at by multiplying the number of houses by five, and this duty was entrusted to an uneducated police. But of late much more careful enumerations of the people have been made, showing that on the night of the 10th January, 1865, there were 30,006,068 in the North-Western Provinces; that in 1866 there were 9,068,103 in the Central Provinces; that in 1868 there were 17,611,498 in the Punjab; that in 1869 there were 11,232,368 in Oudh; that in 1867 there were 2,220,074 in Berar; and that in 1869 there were 2,395,988 in British Burma. Assuming the correctness of the Parliamentary return of the population of non-feudatory India, England rules 212,671,621 people in ten Provinces, containing 221 districts or counties, and in 153 states, covering an area of 1,577,698 square miles. The density ranges from 474 per square mile in Oudh to 26 in British Burma. Over all India it is 135, in feudatory India alone it is 80.

Besides the Annual Administration Reports, the Government of India, the ten Provincial Administrations, and the great Departments issue frequent Reports, some of them of the highest value. All may be consulted in the garrets to which the India Office in Westminster banishes its fine Library and Museum, as well as the weekly reports on the native press, and a copy of every work published in India and registered under the Literature Act. But the Government of India is most liberal in distributing its reports. If any great Association or Library desires a copy of each as it appears in India, an agent should be appointed for its reception in Calcutta. Before the late Mr. Halkett's death the author had the satisfaction of obtaining from Lord Mayo's Government a promise to present a copy of every Report to the Advocates Library of Edinburgh. The Government of India has everything to gain from the widest publicity. The Reports of its great Surveys and of the settlement of the land revenue of every district out of Bengal, are mines of valuable information regarding the country and the people. Much of this is being utilized in the Gazetteers which are being prepared in every Province.

A Director of Indian Statistics has recently been appointed by Lord Mayo, and a Census of all India is about to be made.

On the Scientific Aspects of Children's Hospitals. *By* William Stephenson, *M.D., F.R.C.S. Ed., Phys. to Roy. Hosp. for Sick Children, Edinburgh.*

A peculiarity of Medical Charities is that they exist not only as benevolent in-

stitutions, but occupy a very important position as fields for scientific inquiry, and as means for increasing and diffusing medical knowledge. This double nature brings them directly under the recognition of a scientific association such as this, whose great aim is to develope the high function of science—the promotion of the welfare of mankind. Some details regarding the Royal Hospital for Sick Children were given. It contains 74 beds, 32 for ordinary patients and 42 for fever cases. There is also an outdoor or dispensary department. The patients have likewise the benefit of the Convalescent House at Corstorphine. No letters of introduction are required—the doors are open to all who are sick and young. The liability to abuse which this peculiarity gives rise to was pointed out, and how it lets in the evil of indiscriminate charity.

Important as is the question of the proper administration of charity, it is the scientific economy of the subject which falls more directly under the recognition of this Association. As charities, our hospitals for children have already reached a full maturity, as scientific centres their development is still imperfect and stunted.

The scientific requirements prove the necessity for children's hospitals as separate establishments. To arrive at any important clinical results, requires the grouping together of large numbers of cases, such as only can be done in hospitals of considerable size. They must be also under the care of able men, who should be enabled to devote a large share of their time to the special work. In both these respects the progress of medical science is still greatly retarded in this country. Our children's hospitals are too small, and in London the tendency at present is to multiply the number, rather than increase the size of those already existing, to the proportion commensurate with the requirements of science. Much may be said in favour of small *general* hospitals, but there already exist the necessary large institutions of this kind, and were these divided, science would suffer in proportion to the subdivision.

On the Continent children's hospitals have for years existed on a scale which it is hopeless ever to expect in this country. But it is to them we are indebted for much of our present knowledge of infantile pathology; and on this account our ideas still bear a foreign stamp, which does not prepare us for the modifications which climate, mode of life, and national differences produce in the nature of disease.

One of the great objects in establishing the Children's Hospital was to meet the want in the Edinburgh Medical School of proper "appliances for affording substantial assistance and practical instruction in the diseases of children." That defect has been supplied; the public has nobly done its share in the work, and regular instruction is now given to the students who avail themselves of the opportunity. But at the same time no advance has yet been made by our Universities or Licensing Boards of the country to give that recognition to the subject, without which the resources thus supplied must remain very partially taken advantage of by our students. It is an anomalous fact that medical men obtain their diplomas, and go forth to practise, without having received any special instruction in that department of their profession which is to form two thirds of their patients, and which relates to the causes which are producing the greatest mortality in the country. Special instruction in the physiological, pathological, and clinical peculiarities of childhood holds no real place in the curriculum of study assigned to medical students, and they pass from our schools ignorant of the simplest points of infantile hygiene, or the character of the most important constitutional affections.

This constitutes the great barrier which exists to the full development of one of the great objects which have called our children's hospitals into existence. By the removal of it alone can we expect to combat with greater success, with the widely spread, the far reaching in point of time, and grievously fatal influences, which strike sorrow into our hearts, and carry suffering to those who are dearest and most dependent upon us.

On the Relation between British and Metrical Measures.
By G. Johnstone Stoney, *F.R.S.*

On the Manual Labour Classes of England, Wales, and Scotland. *By* W. Tayler, *F.S.S.*

On Census Reform. *By* James Valentine, *of Aberdeen.*

The object of this paper was to advocate the more frequent taking of the census of the people, and some changes therein, especially in the case of large towns, in order more particularly to ensure a broad and sound basis for our vital statistics.

The author suggested that the following arrangements should be adopted :—

1. A census, confined perhaps to the numbers of the people, the sexes, the ages on the classification of the Registrar-General's Vital Statistics—under 5, 5–20, 20–60, 60 and above; and perhaps the numbers at work and at school respectively should be taken every year, or every two years.

2. The census should be taken under the superintendence of local authorities (say town councils), acting with imperial sanction and at local expense.

3. As to the mode of carrying out the plan, cards might be delivered to every household a week or two before the census-day (say, by the letter-carriers, with some assistance, if necessary); and the citizens should be required to attend at district recording places, and give in these cards, properly filled up, to one or more sworn officers, appointed to receive them. Those unable to fill up the card might give the particulars *vivâ voce*; or the whole census might be taken and recorded in this way.

4. Each district might be a town parish, and there should be manageable blocks or subdivisions, marked out so that the population and other census particulars of each be distinctly recorded.

5. For providing other particulars, of what the author called sanitary geography, as regards the dwelling-houses there should be a surveyor, with access to the valuation roll; and the medical officer of the place would find in this province profitable use for his services in various ways.

6. The figures, on being summed and duly authenticated, would be transmitted to the Registrar-General, and the results adopted by him.

7. There should, however, be a local publication of detailed particulars, popularly stated, and full publicity given to it.

Should this machinery appear at first sight too elaborate, the present system, cumbrous and unsatisfactory in several respects as it is, might be continued, but with a quinquennial instead of a decennial census, and annual returns procured by some simple machinery made, showing the exact population of a place, with the ages at four periods of life; or, again, to reduce the reform to a minimum, the proposed change might apply to towns only, though there is no difficulty about ascertaining the population of a country parish, and it is better to have strict accuracy.

On the Organization of Societies, nationally and locally considered. *By* R. Bailey Walker, *Manchester.*

The object of this paper was—1, to show the ineffectiveness of the present system of separate societary organization; 2, to suggest an elementary step in the direction of further or *inter*-societary organization, and to show its national and local application; 3, to contrast the economy of positive, and the wastefulness of negative (opposition) work, and therefore to urge work of a positive character only, as being consistent with a right understanding of social economics.

On the Law of Capital. *By* William Westgarth.

In bringing up this contentious and oft-told tale of capital once more, the author said, by way of excuse, that he would try to make it thoroughly practical, and one from the merchant's view rather than that of the systematic economist. The awful accounts just being received of the effects of famine in Persia show the importance of capital to any country. Such sudden and frightful misery could not occur in

presence of large capital, simply because capital consists to a large extent of those requisites of life that make our daily food. Hence the importance, for any such emergency, that a country have a large instead of a small capital, that it carry on its business with a large instead of a small current balance of all the things dealt in. The object of the paper is to set forth the causes by which capital arises and increases or decreases in a country, to set forth, in short, the law of capital.

In speaking of Persia, it will be said at once that an element of political or social insecurity readily accounts for a permanently small capital. That is both true and obvious, and therefore the author confined himself to countries that are, in a general way, of equal civilization and security, in order that our law of capital may more clearly show itself. Take then most of the European States, and average them respectively in their soils, forests, mines, in their respective climates. Their industry is all thoroughly organized, and the respective governments, although politically unlike, may be assumed as equally protective of the private rights of property. They seem thus fairly matched for the commercial race, and yet they arrive at very different results, for some have come to much greater wealth than others. Our own country in particular has reached a surpassing position in this respect, with capital ever overflowing to make up the deficiencies of its neighbours.

When we ask for the causes of this in countries that, as we saw, appeared so equally balanced in the substantials of the race, we shall find one dissimilar condition that has not been alluded to, namely, the mode of a country's industry or trading. It is of a more aggregative or wholesale character in one country than another. As matter of fact, we can perceive that the more aggregative industries carry with them the largest capitals, and our business now is to inquire how this is so. How does capital arise, how maintain itself, how increase or diminish?

There is no need at this time of day to explain the economic doctrine of the subdivision of labour, by which industry is made more productive. That is ostensibly and mainly a question of the law of production; but the author deals with the part of the subject that has to do with the law of capital. Let us for a moment go back to that primitivism that must have preceded subdivision of labour amongst early mankind generally, and that still lingers amongst existing barbarism. There is no trading in that social condition. The family, with its fitful industry and its few wants, works only for itself. The only property such a society can have is the home or the homestead of each family, whatever these may be like. There is no exchanging and no exchangeable property, no capital in the commercial sense.

From this isolative aspect of industrial life let us turn to the other, with which we are more familiar. With advancing civilization society has lapsed or drifted of itself into labour-subdivision, from a practical perception that its labour-power is thus turned to better account. Let us follow this arrangement and note how a fund or capital, that had no previous existence, arises out of it. Where the family no longer supplies directly its own wants, but is occupied in each case over only one or a few of society's many various requirements, there comes concurrently, of course, a system of mutual exchange of products. The different households of a town or district fall in this way into intertrading, and by extension of the same principle the trading extends by degrees to adjacent communities, to adjacent countries, and to the world in general. But all this trading requires a trade-apparatus. When the families of a community begin to intertrade, each requires some little stock on hand, according to its extent of custom; others need a factory, or a warehouse, or a shop, and a stock in trade is piled up, according to the wants of each case. When one community trades with another the aggregation of industry and its wholesale dispositions are still more marked, and all the stocks and other apparatus of intertrading are on a proportionately greater scale. There are roads and railways for the inland, and ships for the sea-transportations, and greater stocks and machinery and agency everywhere.

All this may be called the trading expenses. They constitute, indeed, an expensive accompaniment, which would not be willingly maintained by traders, were it not essential to the kind of trade they carry on, and were it not paid for, and something more, by the progressive economy of production accompanying every such step in this aggregative or wholesale direction of industry. This, then, is our

law of capital, that the concurrent apparatus of trade is great in proportion to the aggregative or wholesale tendencies of a country's industry, and that every country's capital is substantially this apparatus of its trading.

To enable any country to attain the condition of relatively large capital, its industry must be left as free as possible to take those aggregative forms into which it is ever naturally impelled by the greater productive results, or, in plainer language, by the larger profits. But here the realities of things present constant obstacles, which keep, and possibly ever will keep, some countries poor in capital and others rich, although we cannot doubt that each and all would prefer to be countries of large means. Even granting that the industrial tendencies and spirit of enterprise are equal and alike in the more advanced countries, a proposition, however, which we hardly dare affirm, yet in various other respects those forms of trading which result in a large capital, are checked and thwarted by the countries themselves, now by their revenue necessities requiring import duties with their trade-restrictive effect, and again by the prejudices and errors of those countries in misdirecting industry by making these duties protective of home industry. To foster home industry at the expense of foreign trade is to restrict the aggregative tendencies of industry, and concurrently, as we have seen, to reduce the requirement or capacity of a country for capital. To "protect" the home industry in addition, is to impoverish the country in its productive power. There is thus the double disadvantage of a diminished productive power, and a reduced amount of that concurrent balance on hand that is regulated more or less by the form of the trading.

The author has not encumbered his argument with the consideration of what is called "fixed capital." He has hitherto been treating of "floating capital," while a country's capital consists of both. The fixed portion is less amenable to the law indicated than the other kind; but inasmuch as the amounts that are ever passing into fixed capital, that is, into permanent investments, depend mainly on the effectiveness of industry in supplying the means, and as this depends on the aggregative and wholesale tendencies, the connexion of all capital is thus more or less direct with the law in question.

In all the foregoing the question is treated on purely business principles, and society regarded as one individual interest, which makes more or less of income at the year's end, and has more or less of concurrent capital all along, according to the form of trading. The social question is of course different, and it takes society to pieces to ascertain how its many individual components fare comparatively under these trading forms. The author did not go into this latter question further than to acknowledge that the social by no means follows always the merely economic well-being. Nevertheless it is of the very highest importance that the economic laws be clearly understood, and that in withstanding their natural tendency, or, in plainer words, in resisting more or less the course of free trade, a country is accepting a positive material disadvantage as the concurrent price or penalty of whatever it is aiming at socially. When the judgment is thus enlightened protective intervention will always be the very rare exception, and only under the strictest and most special discrimination as to what is protected. This would be altogether a different procedure from that blind and indiscriminate protective system with which so many countries still injure themselves, alike by reducing their industrial power and diminishing that concurrent capital requirement or capacity, which keeps a country full-handed in resources.

MECHANICAL SCIENCE.

Address by Professor Fleeming Jenkin, *F.R.S., President of the Section.*

Ladies and Gentlemen,—In addressing you on the subject of mechanical science in our ancient university, I propose to speak on the somewhat threadbare topic of technical instruction. The panic with which some persons regarded the

rapid improvement made abroad in manufactures has subsided; but I hope that you will be all the more ready on that account to listen to a few suggestions as to steps which may be immediately taken to improve the education of those who apply science to practical ends. The subject does not owe its prominence to any events of to-day or of yesterday; it has long been, and will long be, of paramount importance to this country that the education of the producers of wealth should be such as will enable them not merely to compete on advantageous terms with foreigners, but rather to master the great forces of nature by which we work. That we have gained some triumphs can be no reason for relaxing our efforts. With each advance further advance becomes more difficult, and requires more knowledge; the first rude implements and processes employed by man certainly required for their explanation or acquirement no book-learning, but as processes become complex and implements develope into machines, as the occupations of men differ more and more, practice alone is found insufficient to give skill, and study becomes the necessary preparation for all successful work. Our first engineers were not learned men; strong good sense and long practice enabled them to overcome the comparatively simple questions with which they dealt. All honour to those great men; but we who have to deal with more complex, if not with vaster problems, cannot trust to good sense alone, even if we possess it, but must arm ourselves by the study of science and its application to the arts. This being granted, how shall it be done? I need not trouble you by refuting the absurdities of a few men who would have those things taught at schools which have hitherto been taught by practice. What has been taught by practice must still be taught by practice. The business of the school is to teach those things which practice in an art will not teach a man. Let us apply this principle to engineering—the most scientific of all professions. It will be most useless to lecture on filing and chipping; it will be useless to describe the mere forms and arrangements of vast multitudes of machines; one kind of knowledge of the properties of materials can only be acquired, as it always has been acquired, by actually handling them; and the knowledge of the arrangement of a machine is far better learnt by mere inspection than from fifty lectures; moreover, it can be acquired by an intelligent man even if he be wholly unlettered. Book-learning about estimates, the value of goods, methods of superintending work, and dealing with men is foolishness. Written descriptions of puddling a clay embankment, excavating, and such operations, give no knowledge; and yet a vast mass of such knowledge must at some time of his life be acquired by the engineer, and the student cannot be employed as an engineer until he has laid up a store of such knowledge. Colleges cannot give him this; he must serve an apprenticeship in fact if not in form. Young foreigners taught in colleges serve their apprenticeship, at the cost of their employers, during the first few years of their professional life. We call the tyro an apprentice or pupil, and he pays his master instead of being paid by him. I have the strongest feeling against any attempt to substitute collegiate teaching for practical apprenticeship. So far as colleges attempt to teach practice they are and will be a sham in this country and in all others. The work of a college is to teach those sciences which are applied in the arts, but it can go a little further and indicate to its students how the application is made in at least a few selected instances. Applying this dictum to the education of an engineer, his college can teach him mathematics, natural philosophy, chemistry, and geology. No one can doubt that a youth well trained in these branches of knowledge will, even with no further teaching, learn more during his apprenticeship, and during his whole professional life will take a higher standing than the man of equal intelligence untrained in science. College can, however, do more than this; it is found that a lad will go through a considerable number of books of Euclid, and yet see so dimly how his knowledge is to be connected with practice that he may be unable even to compute the area of a field, the dimensions of which are well known to him; and far more is it seen that a man may be fairly grounded in mathematics, and yet have very little idea how to apply his knowledge to mechanical problems. It is the business of those who hold such chairs as mine to point out the connexion between pure science and practice, to show how mathematics are employed in mensuration and in mechanical calculations, to show how the truths of physics are made use of in designing economical machinery, as when we teach the connexion between

the laws of heat and the steam-engine. The student who has once grasped the fact that there is a real connexion between practice and theory will seldom be at a loss how to find or search for that connexion in after life. The student thus prepared knows what he has to learn from practice, and need not lose precious time in blundering over the numberless scientific problems which practice is sure to suggest but can never solve. The education of the architect, the practical chemist, the manufacturer, and the merchant must be similar, *mutatis mutandis*, with that of the engineer. Assuming then that the education of those who are to follow more or less scientific pursuits must consist in acquiring, first, that theoretical knowledge which practice cannot give, and, secondly, the practical knowledge which schools should not attempt to give, there remains the question whether the theoretical preparation should be given in special colleges or universities such as our own. I have no hesitation in preferring the university. Mathematics, physics, chemistry, geology, botany, languages, all form elements required in various combinations in the education of all our students. There is but one kind of mathematics, one kind of pure physics, and so forth. Surely it is better that we should teach the men belonging to different professions side by side, so long as the matter taught is to be the same. There are many dangers in an opposite course. There are not a sufficient number of competent teachers to allow of much differentiation. Segregation at an early age is apt to foster professional peculiarities and narrow-mindedness. There is great danger, if physics are to be taught specially to engineers, that a special kind of physics, erroneously supposed to be specially useful to them, will be invented. Lastly, the contact of students and professors of one faculty with the students and professors of other faculties is very beneficial to all. Do not, therefore, cripple old universities by withdrawing from them a portion of their students and their professors, to set up special professional or technical colleges of a novel kind, but rather add by degrees to the power and usefulness of old institutions, and found new colleges and universities after the model of those which are found to have done good work. As an example of what may be safely done, I consider that in Edinburgh we require a chair of architecture and lectureships on navigation and on telegraphy. There is, further, much want of a teacher of mechanical drawing. The professors of physics and chemistry require additional accommodation for practical laboratories, and additional assistance. If these additions were made our college would, in my opinion, meet all the requirements for superior technical education in this part of Scotland. For £2000 per annum all these additions might be made. Notwithstanding the acknowledged importance of education, establishments for giving the higher kinds of instruction are never self-supporting, and students must everywhere be bribed to come and learn. Immediate prizes, in the form of bursaries, scholarships, and fellowships, are required to induce men to cultivate the older fields of learning; and similar bribes are needed to promote the tillage of the more recently colonized domains of applied science. The Whitworth scholarships are a noble example of munificence thus directed, although, in my opinion, the examination requires considerable reform. I hope that further benefits of this kind will be conferred on those colleges which give efficient teaching. Local ambition is most effectually stirred by local prizes; and I regret to find a certain apathy among students here with respect to the Whitworth competition. This appears to arise partly from dissatisfaction with the mode of examination, and partly from the fact that the examiners are men not well known in Scotland. Leaving the question of technical training for the upper classes, and the still larger question of scientific teaching in second-grade schools, the consideration of which would lead us too far a-field, I propose to say a few words on the technical education of the skilled artisan. This we must treat on the same principles as have been applied to professional teaching. We must endeavour to prepare the lad in school by teaching him those things which he cannot learn in workshops, but which will enable him to work with greater intelligence while acquiring and applying his practical knowledge. I shall not now speak of that general education which should make him a good man, and which should open to him those great sources of rational enjoyment arising from culture; I will restrict myself entirely to his preparation for becoming an efficient workman. I have in many places said, and I cannot say too often, that the great want of the workman is a knowledge of mechanical drawing. Unfortunately I can

obtain little attention from the general public to this demand for the workman. Very few persons not being engineers know at all what mechanical drawing is. I am sorry to say that some examiners in high places, who direct the education of the country, know very little more than the general public, and teachers who should give bread give chaff. I have lived much abroad, and come into close contact both with English and foreign workmen, and I unhesitatingly say that the chief, if not the only inferiority of Englishmen has been in this one branch of knowledge. I must explain to some of my hearers what mechanical drawing is. It is the art of representing any object so accurately that a skilled workman, upon inspecting the drawing, shall be able to make the object of exactly the materials and dimensions shown without any further verbal or written instruction from the designer. The objects represented may be machines, implements, buildings, utensils, or ornaments. They may be constructed of every material. The drawings may be linear, shaded and coloured, or plain. They must necessarily be drawn to scale; but various geometrical methods may be employed. The name of mechanical drawing is given to one and all those representations the object of which is to enable the thing drawn to be made by a workman. Artistic drawing aims at representing agreeably, and for the sake of the representation something already in existence, or which might exist. Mechanical drawing aims at representing the object, not for the sake of the representation, but in order to facilitate the production of the thing represented.

Now I say that it is this latter kind of drawing that is so vastly important to our artisans, and hence to our wealth-producing population. Very few workmen or men of any class can hope to acquire such excellence in artistic drawing that their productions will give pleasure to themselves and others; but a great number of workmen must acquire some knowledge of the drawings of those things which they produce, and there is not one skilled workman who would not be better qualified by a knowledge of mechanical drawing to do his work with ease to himself and benefit to the public. Mechanical drawing is a rudimentary acquirement of the nature of reading, writing, and arithmetic. In order that a man may understand the illustrated description of a machine he must understand this kind of drawing. To the general public an engineering drawing is as unintelligible as a printed book is to a man who cannot read. The general public can no more put their ideas into such a shape that workmen can carry them out than persons ignorant of writing can convey their meaning on paper. Reading and writing on mechanical or industrial subjects is impossible without some knowledge of the art I am pressing on your attention. This art is taught abroad in every industrial school; a great part of the school time is given up to it. In a Prussian industrial school one third of the whole time is given to it. A French commission on technical education reported that drawing, with all its applications to the different industrial arts, should be considered as the principal means to be employed in technical education. Now, I deliberately state that this subject is not taught at all in England, and that the ignorance of it is so great that I can obtain no attention to my complaints. A hundred times more money is spent by Government to encourage artistic drawing than is given to encourage mechanical drawing, and I say that mechanical drawing is a hundred times more important to us as a nation. Moreover, the little *quasi* mechanical drawing which is taught is mostly mere geometrical projection, a subject of which real draughtsmen very frequently, and with little loss to themselves, are profoundly ignorant. Descriptive geometry and geometrical projection are nearly useless branches of the art, and the little encouragement which is given is almost monopolized by these. Mechanical drawing proper is confined to those who pick it up by practice in engineering offices. These draughtsmen are often excellent; and on their behoof I claim no other teaching. I speak for the artisan who makes and for him who uses machinery.

There are two ways in which our shortcomings may be remedied: first, the schools of art now established in this country should be enlarged so as to teach real mechanical drawing, and the examinations conducted by the Science and Art Department should be greatly modified; secondly, the drawing which is to be taught in the schools under the superintendence of the new school boards may be, and ought to be, mechanical drawing. Freehand drawing as a branch of primary

education will, I fear, be a useless pastime; but whether that be so or not, I am certain that the accurate and neat representation of the elementary parts of machinery and buildings would be popular with the pupils and could be effectively taught. This kind of drawing educates hand and mind in accuracy, it teaches the students the elements of mensuration and geometry, and it affords considerable scope for taste where taste exists. The chief difficulty will be to obtain competent teachers. I should occupy you too long were I to attempt to show how these must themselves be trained. My chief aim to-day has been to claim attention for a most important and wholly neglected branch of education.

I shall probably be expected to urge the teaching of other natural sciences in our primary schools; nothing, indeed, would give me greater pleasure than to think this could be done. I confess I doubt it; while our second-grade schools are what they are in this respect, and while the Cambridge examination for a degree in applied science is what it is, I dare not think of natural-science classes in our primary schools. I shall be delighted if I am mistaken; but I am certain that mechanical drawing deserves our first attention, as most immediately useful to the artisan and most easily taught. The very books on natural science which are published in England cannot be properly illustrated for want of a sufficient number of competent draughtsmen; and children would be unable to follow the illustrations and diagrams if ignorant of the principles on which they are constructed. I look rather to good reading-books, explained by intelligent masters, as the best manner of teaching the elementary and all-important truths of natural science. No man could do better service than in compiling such reading-books, and there are few wants more urgent than that of masters competent to enlarge upon texts which would thus be put into their hands. The education of our workmen is far more incomplete than that of our professional men. Small additions to existing institutions will meet the want of the latter; but for the former the institutions have to be erected almost from the foundation.

On an Apparatus for working Torpedoes. By Philip Braham.

The author of this paper described the various modes of working with torpedoes now extant, and explained their various disadvantages. He then explained his own, which was the propulsion of a torpedo from an invulnerable boat below its water-line by means of the expansion of compressed air. A drawing of the apparatus was exhibited by the author; it consisted of a compression-chamber, in which air could be confined to a great pressure, a tube through which the torpedo could be propelled, and a valve arrangement whereby the progressive velocity of the torpedo could be regulated. By means of machinery driven from the engines that move the ship he proposed to compress air into the compression-chamber to 500 lbs. to the square inch, and when within striking-distance of the vessel attacked the air to be suffered to escape behind the shaft of the torpedo, driving it with considerable force so as to strike the vessel attacked below its water-line and then to explode. By the reaction of the force driving the torpedo forwards, whose average statical pressure would be 85 tons on a diameter of 1–9 shown, the author expects the attacking boat would have its speed considerably diminished, if not entirely neutralized, and so prevent the possibility of collision.

Account of some Experiments upon a "Carr's Disintegrator" at work at Messrs. Gibson and Walker's Flour-mills, Leith. By F. J. Bramwell, *C.E.*

Carr's Disintegrator, as is probably well known to most mechanical engineers, consists essentially of two disks, each fixed upon a horizontal shaft. These shafts are placed in one line; the disks which they carry at their ends are separated the one from the other by a space of a few inches. Each disk carries a number of bars or studs disposed in several concentric rings, and standing out at right angles from its face. The concentric rings of studs of the one disk are arranged so as to be in the spaces between the concentric rings of the other disk. The disks are driven in opposite directions, and at a high velocity. The rings of studs, although very

numerous, do not reach to the centre of the machine; this part is unoccupied by studs, and acts as an "eye" to receive the feed. The first two or three rings of studs, beginning at the centre, are fixed to one of the disks only, viz. the one opposite to that through which the feed enters, and they serve to distribute that feed equably throughout the machine. So soon as the material has, however, passed by centrifugal force beyond the limit of the outermost of these central or "eye"-rings, it is met by the first of the rings moving in the opposite direction. The studs of this ring find the material while in mid air and moving in a direction opposite to their own motion, and with a velocity due to the circumferential speed of the ring of studs the material has just quitted. The result of this meeting is clearly, first a violent blow, and then a reversal of motion, by which the whole of the material is sent flying through the air in a direction contrary to that which it last had, and with a velocity increased by the increased circumference of the ring of studs which has just put it into motion, a velocity and a direction, however, to be all but instantly arrested and reversed by the action of the next ring of studs, and so the material proceeds from ring to ring until it is delivered, completely pulverized, at the circumference of the machine. It will have been gathered from this description that a Carr's Disintegrator acts to reduce material upon a principle wholly different to those principles upon which millstones, edge-runners, crushing-rolls, rumblers, and stampers act; in fact, so far as the writer of this paper is aware, upon a principle which had never been applied to a similar or even to an analogous purpose, and that principle is the breaking up of the material by the action of a force which has no other abutment, if the term may be used, than the momentum of the material itself. In fact the material is treated as a shuttlecock, to be bandied backwards and forwards between mechanical battledores, suffering breakage at each blow until it is reduced to the required condition of pulverization.

The proportions of the machine and the size of the spikes or studs are varied to suit the material to be operated upon.

The particular machine upon which the experiments (the subject of this paper) were made is used for converting wheat into flour. It is about 7 feet diameter, and has a space of 10 inches between the faces of the two disks. The disk on the feed side carries six concentric rings of studs, which work between six concentric rings on the opposite disk. This opposite disk has also three "eye"-rings. The studs are circular, half an inch in diameter, and made of crucible steel. The distance from centre to centre of the studs is $2\frac{1}{2}$ inches, and from centre to centre of the rings also $2\frac{1}{2}$ inches, so that there is a clear space both circumferentially and radially of 2 inches between the studs. The revolving disks are enclosed in a casing, at the bottom of which there is an ordinary creeper or screw to convey away the meal produced; and as now very commonly applied to the cases of millstones, there is an exhaust-pipe connected with an exhaust-fan, to remove the dust and convey it to a depositing chamber, the "stive" room. The machine is driven from a counter shaft by means of two straps, one open, the other crossed, so as to give motion in opposite directions to the two disks. Their ordinary working speed is about 400 revolutions per minute.

By the great courtesy of Messrs. Gibson and Walker, and with the able assistance of their engineer, Mr. Watson, the writer and Mr. Edward Easton were enabled to make the following experiments to test the power required to drive this machine under varying circumstances. In arranging the programme of these experiments, the writer was particularly desirous of ascertaining whether or not a suspicion he entertained as to a source of consumption of power in the working of the machine was justified by the facts. From a consideration of the number of times the disks revolve in a minute, and of the number of rings of studs, it is clear there must be many thousand settings into motion, and reversals of those motions, per minute of any material within the action of the disks; and it occurred to the writer that although the air within the zone of action of the machine weighed only between 30 and 40 ounces, yet even that trifling weight could not be subjected to such treatment without the consumption of a very considerable amount of power. He therefore determined to ascertain the power required, not only when the machine was working in its normal manner, both with and without feed, but also

the power when working without feed in an abnormal manner, viz. with both the disks revolving in the same direction and at equal speeds. The experiments and their results may be tabulated as follows:—

Power required to drive a Carr's 7-feet Disintegrator under different conditions at about 400 revolutions per minute.

	Gross indicated horse-power.
When converting into flour 20 quarters of wheat per hour	145
When converting into flour 15 quarters of wheat per hour	123
When working in the normal way, but without feed	63
When working with the disks lashed together, so as to revolve in the same direction and at the same speed	19

From this Table it will be seen that when the machine is working abnormally, it only requires 19 horse-power to drive it, this power being employed in overcoming the friction of the journals &c., and in driving the disks while acting on the air, after the manner of an ordinary fan. Directly, however, the machine is put to work in its normal way, so as to deal with the air by repeated reversals, the power mounts up to 63-horse. It will also be seen that to make 15 quarters of wheat into flour requires 60 horse-power more than to work the machine when acting upon air alone, or at the rate of 20 horse-power for each 5 quarters of wheat, a rate that is very fairly corroborated by the increased power of 22 horses, as shown by the Table to be necessary when the feed is increased by 5 quarters, viz. from 15 to 20 quarters per hour.

Further experiments were made with the object of ascertaining the power absorbed whilst running the machine empty at varying speeds. As this, however, could only be done by altering the revolutions of the steam-engine itself, there were practical difficulties attending the experiments which rendered any great range impossible, and also somewhat impaired the accuracy of those which could be made.

The general result, however, showed that the power, as was expected, varied as the cubes of the speeds.

Although it appeared, from the foregoing experiments, that the Carr's machine when running empty takes, in round numbers, 50 per cent. of the power used by it when at work upon 15 quarters of wheat per hour, it must not be supposed that it is an uneconomic machine as compared with mill-stones. On the contrary, both in power consumed and space occupied, the comparison is greatly in its favour. To grind 20 quarters of wheat per hour would require at least 26 pairs of 4 feet 6 millstones at work, and these would demand from 200 to 250 horse-power, and would occupy, including the necessary spare stones for dressing, about fifteen times as much space as the disintegrator.

On this point of "dressing," Carr's machine possesses a further great advantage. With ordinary millstones one sixth of the number are always out of work for this purpose; and not only are they thus idle, but the wages of highly skilled stone-dressers have to be paid. In the Disintegrator nothing analogous to "dressing" is required. The wearing parts are the studs; and judging from appearances, it would be many years before they require renewal. The machine from the principle of its action possessing this peculiarity, that a worn stud, so long as it is strong enough to beat the particles without sensibly yielding to them, will do its work just as well as when it was new.

It would be beyond the scope of this paper to enter into the question of the relative qualities of the products of this machine and of ordinary millstones. It ought, however, to be stated that Mr. Gibson expressed himself to the writer as highly satisfied on this point.

On a direct-acting Combined Steam and Hydraulic Crane.
By A. B. Brown.

On the Rainfall of Scotland. By ALEXANDER BUCHAN, *M.A., F.R.S.E. Secretary of the Scottish Meteorological Society.*

The paper was illustrated by a map of Scotland, showing the average annual rainfall at 290 places, many of the averages being from observations carried on through long series of years. The map brought out the large rainfall in the west as compared with the east—a difference which is strongly marked even in the group of the Orkney Islands. The average rainfall in the west, at stations removed from the influence of hills, is from about 36 to 40 inches; but in the east in similar situations the rainfall is as low as from 24 to 28 inches. In casting the eye towards the watershed of the country running north and south, it is seen that in ascending toward it from the west there occurs a rapid but by no means uniform increase, and in descending from it toward the east a rapid but by no means uniform decrease. The largest rainfalls occur almost wholly among the hills forming that part of the watershed of Scotland which is north of the Forth and Clyde. The places characterized by the heaviest annual rainfall are, so far as observation has yet enabled us to determine, the following:—Glencroe, 128 inches; Ardlui, head of Loch Lomond, 115 inches; Bridge of Orchy, 110 inches; Tyndrum, 104 inches; Glen Quoich, 102 inches; and Portree, 101 inches. At no great distance from several of these places the rainfall is by no means excessive, thus pointing out an enormous difference of climate between places not far apart. Along the watershed of that part of Scotland which lies south of the Forth and Clyde, no such excessive rainfall occurs,—the highest being 71 inches at Ettrick Pen Top 2268 feet high. This diminished rainfall in the south, as compared with that at places further north similarly situated, is due to the mountains of Ireland draining the south-west winds of part of their moisture before they arrive at these parts of Great Britain.

The distribution of the rainfall is very instructive in many districts, as in the valley of the Forth, from the head of Loch Katrine to North Berwick, where the amount varies from 91 to 24 inches; in Clydesdale, where the quantity is greatest at the head and foot of the valley respectively, being considerably less at intermediate places; and along Loch Linnhe and through the Caledonian Valley, where the variations of the rainfall are very great, and strikingly show the influence of purely physical causes, such as the configuration of the surface, in determining the amounts. In all these districts, as well as elsewhere, many cases might be referred to which conclusively prove that the amount of the rainfall is very far from being determined by mere height. In truth it is to local considerations we must chiefly look for an explanation of the mode in which rain is distributed over any district; and hence in estimating the rainfall, particularly of hilly districts, no dogmatic rule can be laid down.

From observations which have been made at fifty places for lengthened periods, it appears that the deficiency of the three driest consecutive years' rainfall from the average, is generally from one fourth to one seventh, but that in some cases it is as great as one third and in others as small as one ninth. Since then the deficiency of the three years of greatest drought has varied from about 33 to 11 per cent.; it is evident, at least in so far as Scotland is concerned, that no dogmatic rule can be given stating a rate of deficiency applicable to all cases.

If those districts were shaded off in which the rainfall does not exceed 30 inches annually, the great grain-producing district of Scotland would be indicated; and it is interesting to note that in those districts which produce the best wheat the rainfall is lower than elsewhere, being in many places as low as 24 inches annually.

On the Rainfall of the Northern Hemisphere in July, as contrasted with that of January, with Remarks on Atmospheric Circulation. By ALEXANDER BUCHAN, *M.A., F.R.S.E.*

On the Great Heat of August 2nd–4th, 1868. *By* ALEXANDER BUCHAN, *M.A., F.R.S.E.*

On a new Mill for Disintegrating Wheat. *By* THOMAS CARR.

In all previous mills and pulverizing machines the material operated on intervenes between, and is simultaneously in contact with two working surfaces. In this mill the disintegration is effected while the material is falling freely or being projected through the air unsupported, and no individual particle thereof, at the moment of disintegration, is ever in contact with more than one portion of the mill, viz. the particular beater striking and shattering it in mid air. It is also the only mill in which the projectile impetus in the material acted on contributes to its own disintegration.

It consists of a series of beaters, formed of bars with open spaces between them, arranged cylindrically on disk-plates, around and parallel with a central axle. Into these disk-plates one end of each bar is rivetted, so that the bars stand at right angles to the faces of the disks, while their other ends are rivetted into rings, which so tie them that each bar is supported by the aggregate strength of the whole. These cylindrically arranged beaters (forming what may be called cages, from the slight resemblance they have to squirrel-cages) are of different diameters, so that when placed, as they are, concentrically one within the other, sufficient spaces may intervene between to isolate each, and give them the requisite clearance, and thus prevent any scrubbing or grinding-action on the material, which might ensue between them if they were rotating in too close proximity.

These sets of beaters, of which for flour fourteen are used, are driven by means of an open and a crossed strap with extreme rapidity in contrary directions to one another, right and left alternately.

The wheat flows in at the central orifice, and is thrown out by centrifugal force from the first cage at a tangent to its circle, and at a speed equivalent to that at which the beaters of the said cage are rotating, when, meeting the beaters of the next cage moving in an opposite direction, its direction is reversed, and it is again thrown outwards to meet the beaters of the third cage, also moving in a contrary direction, and so on with the other cages until (and that in less than a second from its first introduction) the fragments, reduced to fine flour, semolina, and bran, are delivered in a radiating shower alike from every part of the periphery into a surrounding casing, all the beaters (of which there are about 1000) being thus simultaneously effective, and the balance of the machine maintained. Thus, though with these different sets of beaters each acts independently, they are so arranged relatively to one another that not only is a repetition of the blows on the same material thereby obtained, as many times repeated as there are different sets of beaters, but the centrifugal force generated by the rotation of each set is caused to throw the material forward to the next set. Thus the first set of beaters throws it off and dashes it with great violence against the second, the second in like manner against the third, and so on in directions the reverse of that in which each successive set of beaters it strikes is moving, by which means the blows are enabled to act with redoubled energy on the separated particles of matter as they are discharged against them, precisely in the same way that stones are hurled from a sling.

The machine can hardly be impaired by work further than the necessary wearing of the brasses of the four bearings. The crucible steel beaters, it is estimated, should last for ten years at least, and are then capable of being quickly replaced.

It can pulverize easily 20 qrs. of wheat per hour, and dispense with twenty-five pairs of millstones. The percentage of flour from it is nearly the same as from millstones; but the quality of flour from the new mill is greatly superior, it being shattered into a fine granular state, not felled or killed as the bakers call it. The disintegrated flour absorbs more water, forms a raw paste of greater tenacity, and, when baked, a whiter, lighter, and much better keeping bread, with the sweet nutty flavour of the wheat most agreeably preserved.

The cost of production of flour by this system is considerably less than by any other.

Two of the machines have been successfully worked for many months at Messrs Gibson and Walker's Flour Mills, Bonnington, Edinburgh.

On the Corliss Engine. *By* R. Douglas.

On the Gauge of Railways. *By* R. F. Fairlie, *C.E.*

Last year, at the Liverpool Meeting of the Association, the author read a paper "On the Gauge for Railways of the Future," in which he pointed out the capacities of narrow-gauge lines, and showed how unfavourably the railway-system, as at present worked, contrasted with such lines when properly handled. He said that experience had confirmed the views he had then put forth; and he showed, by giving the dimensions of his carriages, both for passengers and for goods, that upon a 3-ft. gauge he is enabled to place stock of ample size and of less weight than can be done on the 3-ft. 6-inch lines. Whatever saving may be effected in first cost may be lost sight of, the great advantage lying in the saving effected in working expenses. Every ton of dead weight saved goes towards securing the prosperity of the line; and if we can obtain the ample platform which the 3-ft. gauge gives, combined with so much saving in weight, there is nothing left to be desired. In concluding, the author referred to one or two prevailing errors which he said existed with reference to the narrow gauge.

The Rhysimeter, an Instrument for Measuring the Speed of Flowing Water or of Ships. *By* A. E. Fletcher, *F.C.S.*

The principle involved in the construction of this instrument is the same as that of the anemometer described by the author in 1869 (Brit. Assoc. Report, Trans. of Sect. p. 48).

A straight tube is placed in the current whose velocity is to be measured, and held in a plane perpendicular to the direction of motion, so that the water flows across the open end of the pipe. This induces a tendency in the water of the pipe to flow out, and so causes a partial vacuum in it.

At the same time another tube, whose end has been bent round through an angle of 90°, is held parallel to the straight tube in such a position that the bent end faces the current. In this the lateral induction is neutralized by the pressure of the current. The difference between the pressures exerted in the two tubes by the action of the flowing liquid is made a measure of its velocity.

In order to accomplish this the tubes which dip into the stream are continued upwards till their ends are on a level with the eye of the observer. These ends are of glass; they are united at the top so as to form in fact one tube, bent in the shape of an inverted U. At the top of the bend, that is, in the centre of this bridge-piece, is a small exhausting syringe or pump. By means of this a partial vacuum can be formed in both of the long tubes whose ends dip into the running water, and the water be made to rise through them into the glass tubes at the top, which form the indicator of the instrument. The water is made to rise so far as to fill but partially the parallel glass tubes of the indicator, in order that a comparison may be made of the heights of the columns. If the terminal tubes below dip into still water, the heights of the columns will be equal, as they are held up by the same pressure; nor will it signify if one of them is further immersed in the water, for their upper ends are connected with the bridge-piece already mentioned. But if there is motion in the liquid into which the terminal tubes dip, a difference of height will be observed; the amount of this difference can be measured by a conveniently divided scale, and from it the speed of the current known.

It is interesting now to observe that the mathematical formulæ which were educed to show the relation between the speed of the current of air, and the difference between the heights of the columns of ether in the indicator of the anemometer, apply correctly also to show the relation there is between the speed of the current of water, and the difference of the heights of the columns of water in the indicator of the rhysimeter.

In the formula $$v=\sqrt{p\frac{gW}{w}},$$

v will be the velocity of the water in feet per second.
g=accelerating force of gravity=32·18 feet per second.
w=weight of a cubic foot of water at 60° Fahr.
p=difference between the heights of the columns of water driven up the tubes measured in inches.
W=weight in lbs. of $\frac{1}{12}$ cubic foot of water.

The formula becomes $$v=\sqrt{p\cdot\frac{32{\cdot}18}{12}}.$$
$$v=\sqrt{p}\times 1{\cdot}638.$$

To test the correctness of this by experiment, a steadily flowing stream was selected. The speed taken by the motion of a body floating on it was found to be 1 foot per second. The difference of the height of the water-columns was 0·375 inch. According to the formula the speed would have been 1·003 feet per second. This close agreement between the results of experiment and of calculation proves the correctness of the calculations, not only as regards the rhysimeter, but as regards the anemometer also.

When the speed of the water or other flowing liquid is so great as to make the difference between the heights of the columns in the indicator inconveniently long, it is easy to introduce a siphon containing mercury. In this the motion will be less in proportion as its specific gravity is greater than that of water.

This is necessary when the rhysimeter is used to measure the speed of ships. The formula then becomes $p=v^2\times 0{\cdot}08736$, where v=velocity of the ship in knots per hour, and p=height of column of mercury in inches. Below is a Table calculated from it; its correctness has been abundantly proved by experience.

Hydraulic-pressure tubes for measuring the speed of ships have been adopted by Pitot, Darcy, Berthon, and Napier, but hitherto they have not been extensively used by sea-going vessels.

TABLE showing the Speed of a Ship as indicated by the Rhysimeter.
$$p=v^2\times 0{\cdot}08736.$$

Knots per hour.	Height of mercury-column, inches.	Knots per hour.	Height of mercury-column, inches.
1	0·087	9	7·08
2	0·35	12	12·58
2·5	0·55	14	17·12
3	0·79	16	22·36
6	3·15	17	25·25

TABLE showing the Speed of Currents of Water as indicated by the Rhysimeter.
$$v=\sqrt{p}\times 1{\cdot}638.$$

Height of water-column, inches.	Speed of current, feet per second.	Height of water-column, inches.	Speed of current, feet per second.
0·01	0·1638	0·40	1·035
0·02	0·2316	0·50	1·158
0·03	0·2836	1·00	1·638
0·04	0·3275	2·0	2·316
0·05	0·3662	4·0	3·275
0·10	0·5178	6·0	4·012
0·20	0·7323	8·0	4·632
0·30	0·8980		

On Steam-boiler Legislation. By LAVINGTON E. FLETCHER, *C.E.*

Although the Committee of the British Association "appointed to consider and report on the various Plans proposed for Legislating on the subject of Steam-boiler Explosions, with a view to their Prevention," are compelled, from the reasons stated in their *ad interim* Report, to postpone the consideration of the measures recently recommended by the Parliamentary Committee, yet it is thought that it would be well to take advantage of the present opportunity to discuss those measures.

The Report of the Parliamentary Committee is briefly as follows:—

The Parliamentary Committee had it laid before them in evidence that there were not less than 100,000 steam-boilers in the country, and that from these there sprung on an average 50 explosions per annum, killing 75 persons and injuring many others, from which it appeared that one boiler in every 2000 explodes annually. It was further stated that steam-boilers were in many instances situated in much-frequented parts of towns and cities, under pavements in thronged thoroughfares, in the lower storeys of houses, and in the midst of crowded dwellings; that such boilers, notwithstanding their dangerous position, were often faulty in construction, and frequently so set that inspection was impossible without removing the brick-work setting, while they lacked proper gauges and necessary fittings.

The Parliamentary Committee arrived at the conclusion that the majority af explosions arise from negligence, either as regards original construction, inattention of users or their servants, neglect of proper repairs, and absence of proper and necessary fittings, while they further considered that the several voluntary associations formed with a view of securing the periodical inspection of boilers had been useful in preventing explosions.

The Parliamentary Committee recommend, not that inspection should be enforced by law in order to render its adoption universal, but that it be enacted that every steam-user should be held responsible for the efficiency of his boiler, the onus of proof of efficiency in the event of explosion being thrown upon him; and further, that in case of a servant being injured by the explosion of his master's boiler, it should be no defence to plead that the damage arose from the neglect of a fellow-servant. The Committee further recommend that coroners in conducting their inquiries on steam-boiler explosions should be assisted by a competent engineer appointed by the Board of Trade, and that these inquiries should not, as at present, be limited to fatal explosions, but be extended to all others, while reports on the result of each investigation should be forwarded to the Secretary of State for the Home Department, and also be annually presented to Parliament.

The effect of these recommendations, if carried into practice, would be to render the steam-user readily amenable to an action for damages, so that those who suffered from the consequences of an explosion would become the prosecutors. Thus the Parliamentary Committee *do not recommend direct prevention by the enforcement of inspection, but indirect prevention by penalty.*

It will be seen from the foregoing that the evidence laid before the Parliamentary Committee endorses the statements made in the Reports to the British Association on the number and fatality of explosions*, while that Committee speaks favourably of the effect of periodical inspection for the prevention of explosions.

Also the opinion of the Parliamentary Committee with regard to the cause of explosions corroborates the views already expressed in the Reports to the British Association on this subject, viz. that explosions are not mysterious, inexplicable, or unavoidable; that they do not happen by caprice alike to the careful and the careless; that, as a rule, boilers burst simply because they are bad—bad either from original malconstruction, or from the condition into which they have been allowed to fall; and that explosions might be prevented by the exercise of common knowledge and common care†. It is satisfactory to have this principle endorsed by the Parliamentary Committee. Explosions have too long been considered acci-

* See Transactions of the British Association, Norwich Meeting, 1868; Exeter Meeting, 1869; and Liverpool Meeting, 1870.

† Transactions of the British Association at the Exeter Meeting, 1869, p. 50.

dental, and to be shrouded in mystery, and this view has seriously arrested progress. Where mystery begins prevention ends. It is now trusted that it will be thoroughly recognized that explosions are not the result of the freaks of fate, but of commercial greed; and this fundamental principle being firmly established, it cannot be doubted that these catastrophes will ultimately, in one way or another, be prevented. Thus it is thought that a most important step has been taken which is a considerable matter for congratulation.

It is also satisfactory that the Parliamentary Committee has recommended that coroners, when conducting inquiries consequent on steam-boiler explosions, should be assisted by scientific assessors, a practice which was strongly urged in the Report laid before the British Association at the Exeter Meeting*. It may, however, be open to question whether it would be better that the engineer, as the Parliamentary Committee recommend, should be appointed by the Board of Trade, or that the coroner should be empowered to appoint two competent independent engineers to investigate the cause of the explosion, and report thereon, as suggested in the Report referred to. But whichever course be adopted, if competent reports be ensured, a public service will be rendered.

Not only, however, should the "*result*" of each investigation be reported to Parliament, but also all the evidence of an engineering character, accompanied with suitable drawings to illustrate the cause of the explosion, so that all the information to be derived from these sad catastrophes might be disseminated as widely as possible.

Further, it is presumed that the reports on explosions which occur in Scotland, where coroner's inquests are not held, will nevertheless be presented to Parliament.

It is most important that the Bill embodying the recommendations of the Parliamentary Committee should provide for other engineers having an opportunity of making an examination of the fragments of the exploded boiler, as well as those appointed by the Board of Trade, otherwise the intervention of the Board of Trade will have a seriously harassing effect. The system practised in Scotland, where the Procurator-Fiscal appoints an engineer to report to him officially, is found very much to impede other investigations; and engineers who have gone all the way from England to visit the scene of explosions in Scotland with the view of giving the facts to the public have been forbidden access to the scene of the catastrophe, so that the Procurator-Fiscal receives information which he does not circulate, while he withholds the opportunity of gaining information from those who would circulate it, and thus he stands in the way of the public good. It is most important that care should be taken that investigations by Board of Trade officers do not have the same obstructive effect in England; and to this end there should be a special provision that the coroner be invested with a discretionary power to admit any suitable parties to make an investigation.

Passing over the consideration of details, it is certainly considered that the three following conclusions arrived at in the Parliamentary Report, first, that as a rule explosions are not accidental but preventible; secondly, that on the occurrence of explosions a complete investigation of the cause of the catastrophe should be promoted by the appointment of a scientific assessor to assist the coroner; and, thirdly, that reports of each investigation should be presented to Parliament: these three conclusions, it is considered, form a foundation from which a superstructure will spring in course of time which must eradicate steam-boiler explosions.

What the precise character of that superstructure should be is a question on which opinions may differ. Some, among whom are the Parliamentary Committee as already explained, prefer a system of pains and penalties to be inflicted on the steam-user in the event of his allowing his boiler to give rise to an explosion. Others prefer a system of direct prevention by the enforcement of inspection, on the following general basis:—They would recommend a national system of periodical inspection, enforced but not administered by the Government, that administration being committed to the steam-users themselves, with a due infusion of *ex officio* representatives of the public. For this purpose they propose that steam-users should be aggregated into as many district corporations as might be

* Transactions of the British Association at the Exeter Meeting, 1869, p. 50.

found desirable; boards of control, empowered to carry out the inspections and levy such rates upon the steam-users as might be necessary for the conduct of the service, being appointed by the popular election of the steam-users in each district, the different boards being affiliated by means of an annual conference in order to promote the harmonious working of the whole system. Its advocates consider that in this way a system of national inspection might be mildly, but at the same time firmly administered, and that it would then not only prevent the majority of steam-boiler explosions, but prove of great assistance to steam-users in the management of their boilers; that it would be the means of disseminating much valuable information; that it would promote improvements; that it would raise the standard of boiler engineering, and prove a national gain.

The question of the relative merits of the two systems, the one, that of direct prevention by enforced inspection, the other, that of indirect prevention by the infliction of penalty, is one of a very complex character, and the more it is discussed the better, and therefore the fullest expression of opinion is requested at this time.

A further topic for discussion on the present occasion is suggested, viz. whether it might not be well to fix a minimum sum, to be exacted absolutely in the event of every explosion, that fixed sum, however, when inadequate to cover the damage done, not to limit the claim for compensation.

Several advantages it is thought would spring from the adoption of this course, both as regards compensation to those injured and the prevention of explosions.

It frequently happens, on the occurrence of disastrous explosions, that boiler-owners are quite unable to compensate those who have been injured. Such was the case last year at Liverpool, where an explosion occurred at a small iron foundry, in October, killing four persons, laying the foundry in ruins, smashing in some of the surrounding dwelling-houses, and spreading a vast amount of devastation all round. The owners of the boiler, which had been picked up second-hand, and was a little worn-out thing, were two working men, who but a short time before the explosion had been acting as journeymen. They were possessed of little or no capital, and were rendered penniless by the disaster. Another very similar case, though much more serious, occurred at Bingley in June 1869, where as many as fifteen persons were killed, and thirty-one others severely injured by the explosion of a boiler at a bobbin turnery. In this case the user of the boiler was only a tenant; and, judging from the ruined appearance of the premises after the explosion, any attempt to gain compensation for the loss of fifteen lives and thirty-one cases of serious personal injury would have been absolutely futile. The plan of imposing a fixed minimum penalty would tend somewhat to meet this difficulty, as the surplus of one would correct the deficit of another, and in this way a compensation fund might be established for the benefit of the sufferers.

Further, this measure would have a good effect upon steam-users, inasmuch as they would then incur a positive liability, which would act as a more definite stimulus than the vague apprehension of an action for damages, in which they might hope to get off. Also, if this penalty were rendered absolute, it would save a vast amount of litigation, and boiler-owners would then see that it was as much to their interest to believe that explosions were preventible as that they were accidental; and such being the case they would soon find out the way to prevent them*.

This definite minimum penalty would also tend to meet the present tendency of boiler-owners to seek to purchase indemnities from Insurance Companies in the event of explosions, rather than competent inspection to prevent these catastrophes, since, if the penalty were made sufficiently high, it would pay an insurance company as well to make inspections and prevent explosions as to adopt comparatively little inspection, permit occasional if not frequent explosions, and pay compensation. As pointed out last year at Liverpool, the principle of steam-boiler insurance by joint-stock companies does not, under the influence of com-

* Steam-users, however, should be exempted from penalty in those cases of explosion resulting from the direct intention of some evil-disposed person, for which the user could not be held responsible, and which might be regarded as an act of conspiracy, intrigue, or plot.

petition, necessarily insure inspection, inasmuch as the number of explosions being one in 2000 boilers per annum, it follows that the net cost of insurance is only one shilling for every £100, which must evidently be inadequate for any description of inspection by way of prevention. Insurance, therefore, as previously pointed out, is cheap, while adequate inspection is costly; so that inspection is opposed to dividend, for which joint-stock companies are clearly established. Some corrective, therefore, is plainly necessary, and this it is thought would in some measure be found by the establishment of a fixed substantial penalty in the event of every explosion, irrespective of the amount of damage done. Also the imposition of a penalty on every inspection-association or insurance company failing to prevent the explosion of a boiler under their care, might have a most wholesome tendency, this penalty being equal and in addition to the one imposed on the owner, and, in like manner, devoted to the support of the compensation fund *.

In conclusion, although entire assent cannot be accorded to the Parliamentary Report, yet it is most cordially wished that every success may attend the adoption of the measures recommended therein, and that they may result in preventing many explosions, and in diminishing the lamentable loss of life at present resulting from the constant recurrence of these catastrophes.

On Designing Pointed Roofs. By Thomas Gillott.

Description of a Salmon-ladder meant to suit the varying levels of a Lake or Reservoir. By James Leslie, *M.I.C.E.* (Communicated by Alex. Leslie.)

So long as the reservoir or lake is full and overflowing the fish may ascend the waste weir if not too steep, and if otherwise properly constructed and furnished, where necessary, with a salmon-ladder; but whenever the water ceases to overflow the waste weir, the means for the ascent of the fish are generally cut off.

The sluices at the outlet of a lake used as a reservoir are in general (though there may be exceptions to the rule) placed at or near the lowest level of the outlet, and the velocity of the current through them is consequently, in most cases, so great that no fish can swim against it until the surface of the water be run down so low as to be near the level of the outlet, and the velocity be thereby reduced; and in that latter case the power to ascend into the lake is of no great value, as the salmon have little or no disposition to *run* during droughts.

This design consists of a series of sluices placed side by side at different levels, each sluice opening by being lowered instead of by being raised, as is the general mode, and each commencing with the salmon-ladder, which passes along in front of the sluices, and is composed of alternate pools and falls. In this design it is contemplated that on all occasions the whole outflow required to run down the stream should be through *only one* sluice at a time, and over the *top* of that sluice, which would open by lowering, and shut by being raised, except in extreme floods, when, for the sake of keeping down the level of the lake, so as to avoid flooding the adjoining lands, or for any other similar reason, it may be necessary to provide a lower outlet, or the means for a more rapid discharge for the water.

Assuming an instance of a lake with a rise and fall on the surface of 12 feet, and that it is full, or just up to the level of the waste weir, the uppermost sluice of the series is opened so that the water may flow over it to the depth of, say, 9 or 12 inches, which depth we may assume to be necessary to give the statutory compensation. The water will then run down the ladder, which is composed of a series of pools formed by steps reaching quite across from wall to wall, the fall from surface to surface of those steps being 18 inches, and the depth of the pools not less than 3 feet. A fish may then easily leap over the successive falls from the lowest to the highest, after which they must take the last leap over the outlet sluice into the lake, that last leap being at first like all the others, 18 inches, but

* The exemption described above in favour of steam-users should also apply under similar circumstances to Inspection Associations or Insurance Companies.

diminishing in height as the level of the lake is lowered, till at last it is nothing, when the level of the lake comes to the same as that of the highest pool. After that, when the surface of the lake gets too low to give the statutory or requisite supply of water over the uppermost stop, the uppermost sluice is shut, and the one next in order of descent is opened, when the fish would have one leap fewer than before, entering the lake by leaping over the second sluice, and then in succession as the level of the lake falls over each of the other sluices, having a leap less at every change, till at last, when the lake comes to be lowered to nearly the level of its lowest outlet, there would be only one leap to take.

On a new System of Warming and Ventilation. *By* J. D. Morrison.

The author called attention to his paper which was read at the Exeter Meeting, and stated that he introduced improvements which had been approved of by the Highland and Agricultural Society of Scotland. He had also built an experimental room, where his system of ventilation might be tested practically.

Chain-Cable Testing, and proposed New Testing-Link. *By* R. A. Peacock, *C.E., F.G.S.*

It is proposed to provide "testing"-links for each new cable, one link to be connected with the cable at each of its ends, and another link to form part of the cable at every 15 fathoms. Each new link will be a flat oval piece of wrought iron, whose thickness will be equal to the diameter of the metal of each ordinary link. The new links will be cut out of a plate of iron, by means of a steam-punch, and will be left by it of the oval form and having three circular holes through, one in the centre and another halfway to each end. The use of the centre hole, which will be $1\frac{1}{4}$-inch diameter for a 1-inch cable, is this:—a piece of cylindrical bar iron, about 6 inches long and a shade less than $1\frac{1}{4}$-inch diameter, is to be inserted into this hole, and by means of this bar one of the 15-fathom lengths can be connected with a hydrostatic press, the other end of the "length" being fastened at the opposite end of the platform by means of another 6-inch bar, and then the testing-strain may be applied. The two other holes are to connect the testing links with the adjoining parts of the cable.

A cylindrical bar of South-Wales iron was tested by the late Mr. Telford, and its increase of length was found to be 11·68 per cent. After the test, and its diameter was reduced from $1\frac{3}{8}$ inch to $1\frac{1}{8}$, it was torn asunder by 43 tons 11 cwt. Therefore if the "length" of 15 fathoms is increased by testing to an amount exceeding (say) 8 per cent. of its original length, its diameter, and consequently its *strength*, will have been too much reduced, and it ought to be condemned. When the stretching is confined within moderate limits so as to justify the tester in stamping and passing it, the actual length may be stamped on the testing-link; and then, when the cable has been exposed to severe strains on service, it may be laid straight along the pier, and each length be remeasured to ascertain if the strain has been too great, and if any part ought to be condemned.

Links have been found to be *cracked* after having apparently withstood the test: therefore each length, after being tested (before being stamped), should be lifted upon a well-lighted bench of the height of a table, and then every link should be examined carefully all over with a magnifying-glass. If any link is found to be cracked, or otherwise defective, the "length" of course ought to be rejected.

On the Carbon Closet System. *By* E. C. C. Stanford, *F.C.S.*

On the Steam Blast. *By* C. William Siemens, *F.R.S., D.C.L., M. Inst. C.E.*

After describing what had previously been done by others, including the researches of Professors Zeuner and Rankine, the author explained an improved steam-blast apparatus which he had invented. This apparatus consisted of three principal

parts, viz.:—(1) a steam-nozzle of annular cross section, discharging steam in the form of a hollow cylindrical body of a thickness of wall of not more than ·02 (one fiftieth) of an inch; (2) a mixing-chamber, with contracted annular inlets for the air, equal in area to its least sectional area, and of a length equal to from five to six diameters; (3) a parabolic delivery-pipe of considerable length, in which the mixed current is gradually brought to the condition of comparative rest, and its momentum or living force is reconverted into potential force or pressure.

The result of a long series of experiments leads to the conclusions:—(1) That the quantitative effect of a steam-blower depends upon the amount of contact surface between the air and steam, irrespective of the steam pressure, up to a certain limit of compression, where the impelling action ceases; (2) that the maximum attainable differences of pressure increase, under otherwise similar circumstances, in direct proportion with the steam pressure employed; (3) that the quantitative effect produced is regulated (within the limits of efficient action of the instrument) by the weight of air impelled, and that therefore a better dynamical result is realized in exhausting than in compressing air; (4) that the limits of difference of pressure attainable are the same in exhausting and in compressing.

It was stated that with this apparatus a vacuum of 24 inches of mercury had been obtained, and that with two of these apparatus a working vacuum of 10 inches of mercury had been maintained at one end of a pneumatic despatch-tube 3 inches in diameter, through which carriers were propelled at the mean rate of about 1000 feet per minute.

Automatic Gauge for the Discharge of Water over Waste Weirs. By Thomas Stevenson, *F.R.S.E., M.I.C.E., C.E.*

The author stated that, in order to ascertain the amount of available rainfall, which is so important in questions of water supply, it is necessary to gauge the quantity of water which escapes at the waste weirs of reservoirs. Observations made only once or twice a day cannot supply the information. It is proposed to place a tube perforated vertically with small holes, the lowest of which is on a level with the top of the waste weir, so that, whenever water passes over the weir, it also passes through the holes in the tube. The water is collected in a tank capable of holding the discharge for a certain number of hours; the quantity so collected is a known submultiple of what passes over the weir. The discharge through the holes is ascertained by experiment. This self-acting apparatus will render the continuous observations of floods unnecessary.

Thermometer of Translation for recording the Daily Changes of Temperature. By Thomas Stevenson, *F.R.S.E., M.I.C.E., C.E.*

The author described what he termed a *thermometer of translation*, which consisted of an expansible body with a needle-point at its upper end, and which, when expanded by the sun, is fixed at its upper end by a needle-point catching into fine teeth cut in a sheet of glass or other material of small expansibility placed below. When the sun is obscured, the upper end being fixed, the contraction raises the centre of gravity of the bar. In this way the daily march or creep of the bar chronicles the change or changes of temperature. Mr. Stevenson also described two different methods, suggested by his friends Professors Tait and Swan, for increasing the amount of expansion of the material employed.

On improved Ships of War. By Michael Scott.

On a Road Steamer. By W. Thomson.

The great feature in the construction of this machine is the use of a very thick india-rubber tire, to the outer circumference of which is attached a chain of flat plates of iron. These india-rubber tires not only completely prevented hard shocks

to the machinery, but saved the road from the grinding-action of the iron wheels which was so injurious to bye-ways. There had been serious objections made to the use of these engines with rigid tires; but the author ventured to assert that the india-rubber tires not only did not injure, but actually improved the roads. The only ground upon which india-rubber tires did not work well was where the soil was extremely wet, or of a very soft and sloppy nature. For farm work, the wheels of the engine required a much thicker coat of india-rubber.

APPENDIX.

Notes on Dredging at Madeira. *By the* Rev. Robert Boog Watson, *B.A., F.R.S.E., F.G.S.*

The difficulties of shell-gathering at Madeira are very many and very great. As the result of several years' work, the author has to record that six or seven species mentioned in MacAndrew's List have hitherto escaped him; that to the one hundred and twenty-seven species named by MacAndrew (besides these he gives twenty-nine unnamed = one hundred and fifty-six in all) the author has succeeded in adding something like two hundred and fifty more, or from three hundred and fifty to four hundred in all; and while these strongly confirm MacAndrew's generalization of the Mediterranean character of the Mollusca, yet a few of them present forms belonging some of them to the tropics, and others to very distant localities, as, for instance, *Ranella rhodostoma* and *Triton chlorostoma*, which Reeve, not perhaps very reliably, assigns, the first to the Islands of Capul and Masbate of the Philippines, and the second to the Island of Annaa in the Pacific. Further, among these two hundred or two hundred and fifty species, eighty or, perhaps, ninety may probably prove to be new species, and three or four new genera.

It is somewhat curious that only one of the author's new species has been recognized by Mr. Gwyn Jeffreys as obtained by him from the 'Porcupine' dredgings.

The publication of full details is contemplated by the author.

On the Ciliated Condition of the Inner Layer of the Blastoderm and of the Omphalo-mesenteric Vessels in the Egg of the Common Fowl. By B. T. Lowne.

Mr. Lowne stated that the number of observations he had at present made were insufficient to substantiate his opinion beyond a doubt, but that he thought it extremely probable, from what he had seen, that, 1st, the inner layer of the blastoderm is ciliated, at least in tracts of its surface. He had several times observed the most marked currents, and he believed, but was not certain, that he had distinguished the cilia.

2ndly. From a single observation he thought that the interior of the omphalo-mesenteric vessels is ciliated. He saw in a portion of the blastoderm of a five-day chick the most marked circulation in the omphalo-mesenteric vessels. In one large vessel, especially where the two cut extremities were blocked with blood-corpuscles, a rapid movement was taking place.

Mr. Lowne stated that he was still investigating the subject.

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[*An asterisk (*) signifies that no abstract of the communication is given.*]

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Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s.* 6*d.*

CONTENTS:—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s.*

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the FOURTEENTH MEETING, at York, 1844, *Published at* £1.

Contents:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

Contents:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

Contents:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s*.

Contents:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s*.

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address and Recommendations of the Association and its Committees.

PROCEEDINGS of the NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s*.

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds; —F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15*s*. (Out of Print.)

Contents:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840 to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16*s*. 6*d*.

Contents:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850 to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15*s*.

Contents:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53; —James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued); —Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55; —Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report

on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15*s.*

CONTENTS:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{t-\alpha} \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{t^{|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $\alpha^{t|+1}$ désignant le produit des t facteurs $\alpha\ (\alpha+1)\ (\alpha+2)$ &c.... $(\alpha+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry;—John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20*s.*

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the

Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857–58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles's paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15s.

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—A. Thomson, Esq. of Banchory, Report on the Aberdeen Industrial Feeding Schools; —On the Upper Silurians of Lesmahago, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858–59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858–59; —Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air;—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15s.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859–60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Professor Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of

Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De la Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Professor G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Professor Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders;—Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

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PROCEEDINGS OF THE THIRTY-SECOND MEETING, at Cambridge, October 1862, *Published at* £1.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee;—Report on Tidal Observations on the Humber;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Do-

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PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at* £1 5*s*.

Contents:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and of the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for Exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.:—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Professor Airy, Report on Steam-boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864. *Published* at 18*s*.

Contents:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS of the THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5*s.*

Contents :—J. G. Jeffreys, Report on Dredging among the Channel Isles ;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods ;—Report of the Committee for exploring Kent's Cavern ;—Report of the Committee on Zoological Nomenclature ;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field ;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall ;—Interim Report on the Resistance of Water to Floating and Immersed Bodies ;—Report on Observations of Luminous Meteors ;—Report on Dredging on the Coast of Aberdeenshire ;—J. Glaisher, Account of Three Balloon Ascents ;—Interim Report on the Transmission of Sound under Water ;—G. J. Symons, on the Rainfall of the British Isles ;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships ;—Report of the Gun-Cotton Committee ;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham ;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds ;—Report on further Researches in the Lingula-flags of South Wales ;—Report of the Lunar Committee for Mapping the Surface of the Moon ;—Report on Standards of Electrical Resistance ;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis ;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field ;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea ;—H. J. S. Smith, Report on the Theory of Numbers, Part VI. ;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science ;—A. G. Findlay, on the Bed of the Ocean ;—Professor A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

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PROCEEDINGS of the THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at* £1 4*s.*

Contents :—Second Report on Kent's Cavern, Devonshire ;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron ;—Report on Observations of Luminous Meteors ;—W. S. Mitchell, Report on the Alum Bay Leaf-bed ;—Report on the Resistance of Water to Floating and Immersed Bodies ;—Dr. Norris, Report on Muscular Irritability ;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl ;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea ;—Second Report on the "Menevian Group," and the other Formations at St. David's, Pembrokeshire ;—J. G. Jeffreys, Report on Dredging among the Hebrides ;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II. ;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report ;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides ;—Report on Dredging in the Moray Firth ;—Report on the Transmission of Sound-Signals under Water ;—Report of the Lunar Committee ;—Report of the Rainfall Committee ;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science ;—J. Glaisher, Account of Three Balloon Ascents ;—Report on the Extinct Birds of the Mascarene Islands ;—Report on the penetration of Iron-clad Ships by Steel Shot ;—J. A. Wanklyn, Report on Isomerism among the Alcohols ;—Report on Scientific Evidence in Courts of Law ;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

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PROCEEDINGS of the THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at* £1 6*s.*

Contents :—Report of the Committee for Mapping the Surface of the Moon ;—Third Report on Kent's Cavern, Devonshire ;—On the present State of the Manufacture of Iron in Great Britain ;—Third Report on the Structure and Classification of the Fossil Crustacea ;—Report on the Physiological Action of the Methyl Compounds ;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland ;—Report of the Steamship Performance Committee ;—On the Meteorology of Port Louis in the Island of Mauritius ;—On the Construction and Works of the Highland Railway ;—Experimental Researches on the Me-

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PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at* £1 5*s*.

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Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough-house, Woodberry Down, Stoke Newington, London, N.
1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.
1863. *Abel, Frederick Augustus, F.R.S., F.C.S., Director of the Chemical Establishment of the War Department, Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1863. *Abernethy, James. 2 Delahay-street, Westminster, London, S.W.
1860. §§Abernethy, Robert. Ferry-hill, Aberdeen.
1854. ‡Abraham, John. 87 Bold-street, Liverpool.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
Acland, Henry W. D., M.A., M.D., LL.D., F.R.S., F.R.G.S., Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1860. ‡Acland, Sir Thomas Dyke, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.
Adair, John. 13 Merrion-square North, Dublin.
*Adair, Colonel Sir Robert A. Shafto, F.R.S. 7 Audley-square, London, W.
*Adams, John Couch, M.A., D.C.L., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.

Year of Election.

1871. §Adams, John R. 15 Old Jewry Chambers, London, E.C.
1869. *Adams, William Grylls, M.A., F.G.S., Professor of Natural Philosophy and Astronomy in King's College, London, W.C.
Adderley, The Right Hon. Sir Charles Bowyer, M.P. Hams-hall Coleshill, Warwickshire.
Adelaide, Augustus Short, D.D., Bishop of. South Australia.
1860. *Adie, Patrick. Grove Cottage, Barnes, London, S.W.
1865. *Adkins, Henry. The Firs, Edgbaston, Birmingham.
1845. ‡Ainslie, Rev. G., D.D., Master of Pembroke College. Pembroke Lodge, Cambridge.
1864. *Ainsworth, David. The Flosh, Cleator, Whitehaven.
1871. *Ainsworth, John Stirling. The Flosh, Cleator, Whitehaven.
Ainsworth, Peter. Smithills Hall, Bolton.
1842. *Ainsworth, Thomas. The Flosh, Cleator, Whitehaven.
1871. §Ainsworth, William M. The Flosh, Cleator, Whitehaven.
1859. ‡Airlie, The Right Hon. The Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.
Airy, George Biddell, M.A., LL.D., D.C.L., F.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich.
1871. §Aitken, John. Darrock, Falkirk, N.B.
1855. ‡Aitkin, John, M.D. 21 Blythswood-square, Glasgow.
Akroyd, Edward, M.P. Bankfield, Halifax.
1861. *Alcock, Ralph. 47 Nelson-street, Oxford-street, Manchester.
1862. ‡Alcock, Sir Rutherford. The Athenæum Club, Pall Mall, London.
1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
Alderson, Sir James, M.A., M.D., D.C.L., F.R.S., Pres. Roy. Coll. Physicians, Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.
1857. ‡Aldridge, John, M.D. 20 Ranelagh-road, Dublin.
1859. ‡Alexander, Colonel Sir James Edward, K.C.L.S., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N.B.
1858. ‡Alexander, William, M.D. Halifax.
1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.
1851. ‡Alexander, W. H. Bank-street, Ipswich.
1869. ‡*Alger, T. L.*
1867. ‡Alison, George L. C. Dundee.
1863. ‡Allan, Miss. Bridge-street, Worcester.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1871. §Allan, G., C.E. 17 Leadenhall-street, London, E.C.
1862. ‡Allan, James, M.A., Ph.D. School of Practical Science, Sheffield.
Allan, William. 22 Carlton-place, Glasgow.
1871. §Allen, Alfred H., F.C.S. 1 Surrey-street, Sheffield.
1861. ‡Allen, Richard. Didsbury, near Manchester.
Allen, William. 50 Henry-street, Dublin.
1852. *Allen, William J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*Allis, Thomas, F.L.S. Osbaldwick Hall, near York.
*Allman, George J., M.D., F.R.S. L. & E., M.R.I.A., 20 Gloucester Road, Regent's Park, London, N.W.
1868. ‡*Allon, Rev. H.*
1866. ‡Allsopp, Alexander.
1844. *Ambler, Henry. Watkinson Hall, near Halifax.
*Amery, John, F.S.A. Manor House, Eckington, Pershore.
1855. ‡Anderson, Alexander D., M.D. 159 St. Vincent-street, Edinburgh.

Year of
Election.

1855. ‡Anderson, Andrew. 2 Woodside-crescent, Glasgow.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1871. *Anderson, James. Battlefield House, Langside, Glasgow.
1852. ‡Anderson, Sir James. Glasgow.
1855. ‡*Anderson, James.*
1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
1859. ‡Anderson, Patrick. 15 King-street, Dundee.
1850. ‡Anderson, Thomas, M.D., Professor of Chemistry in the University of Glasgow.
1870. §§Anderson, Thomas Darnley. West Dingle, Liverpool.
1853. *Anderson, William (Yr.). Linktown, Kirkcaldy, Scotland.
*Andrews, Thomas, M.D., F.R.S., M.R.I.A., F.C.S., Vice-President of, and Professor of Chemistry in, Queen's College, Belfast.
1857. ‡Andrews, William. The Hill, Monkstown, Co. Dublin.
1859. ‡Angus, John. Town House, Aberdeen.
*Ansted, David Thomas, M.A., F.R.S., F.G.S., F.R.G.S. 33 Brunswick-square, London, W.C.
Anthony, John, M.D. Caius College, Cambridge.
1868. ‡Anstie, Francis E., M.D. 16 Wimpole-street, London, W.
Apjohn, James, M.D., F.R.S., M.R.I.A., Professor of Chemistry, Trinity College, Dublin. South Hill, Blackrock, Co. Dublin.
1863. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1859. ‡*Arbuthnot, C. T.*
1870. §§Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *Archer, Thomas C., F.R.S.E., Director of the Museum of Science and Art. 9 Argyll-place, Edinburgh.
1851. ‡Argyll, The Duke of, K.T., LL.D., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London; and Inverary, Argyllshire.
1865. ‡Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.
1861. §Armitage, William. 7 Meal-street, Mosley-street, Manchester.
1867. *Armitstead, George, M.P. Errol Park, Errol, by Dundee.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *Armstrong, Sir William George, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Elswick Works, Newcastle-upon-Tyne.
1856. ‡Armstrong, William Jones, M.A. Mount Irwin, Tynna, Co. Armagh.
1868. ‡Arnold, Edward., F.C.S. Prince of Wales-road, Norwich.
1871. §Arnot, William, F.C.S. St. Ann's Villa, Lasswade, N.B.
Arnott, Neil, M.D., F.R.S., F.G.S. 2 Cumberland-terrace, Regent's Park, London, N.W.
1870. §Arnott, Thomas Reid. 2 Church Road, Seaforth, Liverpool.
1864. §Arrowsmith, John, F.R.A.S., F.R.G.S. 35 Hereford-square, South Kensington, London, S.W.
1853. *Arthur, Rev. William, M.A. Centenary Hall, Bishopsgate-street Within, London, E.C.
1870. *Ash, Linnington. Holsworthy, North Devon.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Turton, near Bolton.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
Aspland, Algernon Sydney. Glamorgan House, Durdham Down, Bristol.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Thomas. 4 Elm-court, Temple, London, E.C.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.

Year of
Election.

1866.§§Atherton, J. H., F.C.S. Long-row, Nottingham.
1865. ‡Atkin, Alfred. Griffin's-hill, Birmingham.
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1869. *Atkinson, Anthony Owst, M.A., LL.D. Clare House, Hull; and New University Club, St. James's, London, S.W.
1865. *Atkinson, Edmund, F.C.S. 7 The Terrace, Sandhurst, Farnborough Station.
1863. *Atkinson, G. Clayton. Wylam Hall, Northumberland.
1858. *Atkinson, John Hastings. 14 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 13 Carlisle-terrace, Kensington, London, W.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, J. R. W.
Atkinson, William. Ashton Hayes, near Chester.
1863. *Attfield, Dr. J. 17 Bloomsbury-square, London, W.C.
**Auldjo, John, F.G.S.*
1859. ‡*Austin, Alfred.*
1860. *Austin-Gourlay, Rev. William E. C., M.A. Stoke Abbott Rectory, Beaminster, Dorset.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1865. *Avery, William Henry. Norfolk-road, Edgbaston, Birmingham.
1867.§§Avison. Thomas, F.S.A. Fulwood Park, Liverpool.
1853. *Ayrton, W. S., F.S.A. Saltburn-by-the-Sea.

Babbage, B. H. 1 Dorset-street, Manchester-square, London, W.
*Babington, Charles Cardale, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Trumpington-road, Cambridge.
Bache, Rev. Samuel. 44 Frederick-street, Edgbaston, Birmingham.
1845. ‡Back, Rear-Admiral Sir George, D.C.L., F.R.S., F.R.G.S. 109 Gloucester-place, Portman-square, London, W.
1867. *Bagg, Stanley Clark. Fairmount Villa, Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, J. W. Sunderland.
Backhouse, Thomas James. Sunderland.
**Baddeley, Captain Frederick H., R.E.*
1870. §Bailey, F. J. 51 Grove-street, Liverpool.
Bailey, Samuel. Sheffield.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1857. ‡Baily, William Hellier, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 51 Stephen's Green, and 24 Kenilworth-square North, Dublin.
*Bain, Richard. Manor Hall, Forest Hill, London, S.E.
1865. ‡Bain, Rev. W. J. Wellingborough.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*Baines, Edward, M.P. 28 Grosvenor-street West, London, S.W.; and Headingley Lodge, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1865. §Baines, Thomas, F.R.G.S. 35 Austen-street, King's Lynn, Norfolk.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. §Baker, Francis B. Arboretum Street, Nottingham.
1858. *Baker, Henry Granville. Bellevue, Horsforth, near Leeds.
1865. ‡Baker, James P. Wolverhampton.

Year of Election.

1861. *Baker, John. Gatley-hill, Cheadle, Cheshire.
1861. *Baker, John. (R. Brooks & Co., St. Peter's Chambers, Cornhill, London, C.E.)
1865. ‡Baker, Robert L. Barham House, Leamington.
1847. ‡Baker, Thomas B. Lloyd. Hardwick-court, Gloucester.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. §Baker, William. 6 Taptonville, Sheffield.
1845. ‡Bakewell, Frederick. 6 Haverstock-terrace, Hampstead, London, N.W.
1860. §Balding, James, M.R.C.S. Barkway, Royston, Hertfordshire.
1851. *Baldwin, The Hon. Robert, H.M. Attorney-General. Spadina, Co. York, Upper Canada.
1871. §Balfour, Francis Maitland. Trinity College, Cambridge.
1871. §Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
*Balfour, John Hutton, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
*Ball, John, F.R.S., F.L.S., M.R.I.A. 24 St. George's-road, Eccleston-square, London, S.W.
1866. *Ball, Robert Stawell, M.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science of Ireland. 47 Wellington-place, Upper Leeson-street, Dublin.
1863. ‡Ball, Thomas. Bramcote, Nottingham.
*Ball, William. Bruce-grove, Tottenham, London, N.; and Rydall, Ambleside, Westmoreland.
1870. §Balmain, William H., F.C.S. Spring Cottage, Great St. Helens.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster Chambers, Victoria-street, Westminster, S.W.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1861. ‡Bannerman, James Alexander. Limefield House, Higher Broughton, near Manchester.
1870. §§Banister, Rev. William, B.A. St. James's Mount, Liverpool.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Kingslee, Farndon, Chester.
1859. ‡Barbour, George F. 11 George Square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A., M.R.A.S. Bury-hill, Dorking.
1871. §Barclay, George. 17 Coates-crescent, Edinburgh.
Barclay, James. Catrine, Ayrshire.
1852. *Barclay, J. Gurney. Walthamstow, Essex.
1860. *Barclay, Robert. Oak Hall, Wanstead, Essex.
1868. *Barclay, W. L. Knott's Green, Leyton, Essex.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgeford Rectory, Notts.
1857. ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. Waterloo-road, Dublin.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. §§Barkly, Sir Henry, K.C.B., F.R.S. Bath.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
Barlow, Peter. 5 Great George-street, Dublin.
1857. ‡Barlow, Peter William, F.R.S., F.G.S. 8 Eliott-place, Blackheath, London, S.E.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.

Year of Election.

1864. *Barneby, John H. Brockhampton Park, Worcester.
1868. §Barnes, Richard H. 40 Kensington Park Gardens, London, W.
*Barnes, Thomas, M.D., F.R.S.E. Bunker's Hill, Carlisle.
Barnes, Thomas Addison. 40 Chester Street, Wrexham.
*Barnett, Richard, M.R.C.S. Avon-side, Coten End, Warwickshire.
1859. ‡Barr, Major-General, Bombay Army. Culter House, near Aberdeen. (Messrs. Forbes, Forbes & Co., 9 King William-street, London.)
1861. *Barr, William R. Heaton Lodge, Heaton Mersey, near Manchester.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1852. ‡Barrington, Edward. Fassaroe Bray, Co. Wicklow.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡Barry, Rev. A., D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. Lapswood, Sydenham-hill, Kent, S.E.
Barstow, Thomas. Garrow-hill, near York.
1858. *Bartholomew, Charles. Broxholme, Doncaster.
1855. ‡Bartholomew, Hugh. New Gas-works, Glasgow.
1858. *Bartholomew, William Hamond. Albion Villa, Spencer-place, Leeds.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
*Barton, John. Bank of Ireland, Dublin.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
1870. §Baruchson, Arnold. Blundell Sands, near Liverpool.
1858. *Barwick, John Marshall. Albion-place, Leeds; and Glenview, Shipley, near Leeds.
*Bashforth, Rev. Francis, B.D. 15 Campbell-terrace, Plumstead, Kent, S.E.
1861. ‡Bass, John H., F.G.S. 287 Camden-road, London, N.
1866. *Bassett, Henry. 215 Hampstead-road, London, N.W.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. §Bastian, H. Charlton, M.A., M.D., F.R.S., Professor of Pathological Anatomy to University College Hospital. 20 Queen Anne-street, London, W.
1848. ‡Bate, C. Spence, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.L.S., F.H.S. 9 Hyde Park Gate, Landon, W.
1842. *Bateman, John Frederic, C.E., F.R.S., F.G.S. 16 Great George-street, London, S.W.
1864. §Bates, Henry Walter, Assist.-Sec. R.G.S. 15 Whitehall-place, London, S.W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡Bath and Wells, Lord Arthur Hervey, Lord Bishop of.
1863. *Bathurst, Rev. W. H. Lydney, Gloucestershire.
1869. ‡Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, S.W.
1863. §Bauerman, Henry, F.G.S. 22 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. *Baxter, Sir David, Bart. Kilmaron, Cupar, Fifeshire.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1870. §§Baxter, R. Dudley, M.A. 6 Victoria-street, Westminster, S.W., and Hampstead.
1867. ‡Baxter, William Edward, M.P. Ashcliffe, Dundee.
1851. *Bayley, George. 2 Cowper's-court, Cornhill, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.

Year of
Election.

1854. ‡Baylis, C. O., M.D. 22 Devonshire-road, Claughton, Birkenhead.
Bayly, John. 1 Brunswick-terrace, Plymouth.
1868. ‡Bayes, William, M.D. Brunswick Lodge, Newmarket-road, Norwich.
1860. *Beale, Lionel S., M.D., F.R.S. 61 Grosvenor-street, London, W.
1833. *Beamish, Richard, F.R.S. Woolston Lawn, Woolston, Southampton.
1861. §Bean, William. Alfreton, Derbyshire.
1870. §§Beard, Rev. Charles. 13 South Hill Road, Toxteth Park, Liverpool.
1866. *Beardmore, Nathaniel, C.E., F.G.S. 30 Great George-st., London, S.W.
*Beatson, William. Chemical Works, Rotherham.
1855. *Beaufort, William Morris, F.R.G.S., M.R.A.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Capt. George G. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London, E.C.
1851. ‡*Becker, Ernest, Ph.D. Darmstadt.*
1864. §Becker, Miss Lydia E. Whalley Range, Manchester.
1860. ‡Beckles, Samuel H., F.R.S., F.G.S. 9 Grand Parade, St. Leonards-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §Beddoe, John, M.D. Clifton, Bristol.
1854. ‡*Bedford, James, Ph.D.*
1846. ‡Beke, Charles T., Ph.D., F.S.A., F.R.G.S. Bekesbourne House, near Canterbury, Kent.
1865. *Belavenetz, I., Captain of the Russian Imperial Navy, F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-street, London, E.C.)
1847. *Belcher, Vice-Admiral Sir Edward, K.C.B., F.R.A.S., F.R.G.S. 22A Connaught-square, London, W.
1871. §Bell, Archibald. Cleator, Carnforth.
1871. §Bell, Charles B. 6 Spring Bank, Hull.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Christ's Hospital, London, E.C.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *Bell, Isaac Lowthian. The Hall, Washington, Co. Durham.
1870. §§Bell, J. Carter. Gilda Brooth, Eccles, Manchester.
1871. *Bell, J. Carter, F.C.S. Gilda Brook, Eccles, Manchester.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
Bell, Thomas, F.R.S., F.L.S., F.G.S., Professor of Zoology, King's College, London. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. The Minories, Jesmond, Newcastle-on-Tyne.
1867. ‡Bell, Thomas. Belmont, Dundee.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. ‡Bellhouse, William Dawson. 1 Park-street, Leeds.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1866. *Belper, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 88 Eaton-square, London, S.W.; and Kingston Hall, Derby.
1864. *Bendyshe, T. The Library, King's College, Cambridge.
1870. §§Bennett, Alfred W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1871. §Bennett, F. J. 12 Hillmarten-road, Camden-road, London, N.
1838. ‡Bennett, John Hughes, M.D., F.R.S.E., Professor of Institutes of Medicine in the University of Edinburgh. 1 Glenfinlas-street, Edinb.
1870. *Bennett, William. Heysham Tower, Lancaster.

Year of Election.

1870. *Bennett, William, jun. Sir Thomas's Buildings, Liverpool.
1852. *Bennoch, Francis. The Knoll, Blackheath, Kent, S.E.
1857. ‡Benson, Charles. 11 Fitzwilliam-square West, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870.§§Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡Bentham, George, F.R.S., Pres. L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 9 Portland-place, London, W.
1863. §Bentley, Robert, F.L.S., Professor of Botany in King's College. 55 Clifton-road, St. John's-wood, London, N.W.
1868. ‡Berkeley, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1866. §Berry, Rev. Arthur George. Monyash Parsonage, Bakewell, Derbyshire.
1870. §Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A. St. John's College, Cambridge.
1865. *Bessemer, Henry. Denmark-hill, Camberwell, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds.
1870. §Bickerton, A. W., F.C.S. Oak House, Belle Vue-road, Southampton.
1868. ‡Bidder, George Parker, C.E., F.R.G.S. 24 Great George-street, Westminster, S.W.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 17 Charles-street, Bath.
1855. ‡Billings, Robert William. 4 St. Mary's-road, Canonbury, London, N.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.; and Chislehurst, Kent.
1842. Binney, Edward William, F.R.S., F.G.S. 40 Cross-street, Manchester.
Birchall, Henry. College-house, Bradford.
Birchall, Edwin. Airedale Cliff, Newley, Leeds.
1866. *Birkin, Richard, jun. The Park, Nottingham.
*Birks, Rev. Thomas Rawson. Trinity College, Cambridge.
1842. *Birley, Richard. Seedley, Pendleton, Manchester.
1861. ‡*Birley, Thomas Thorneley.*
1841. *Birt, William Radcliff, F.R.A.S. Cynthia-villa, Clarendon-road, Walthamstow, London, N.E.
1871. *Bischof, Professor Gustav. Andersonian University, Glasgow.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1863. ‡Black, William. South Shields.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1859. ‡Blackie, John Stewart, Professor of Greek. Edinburgh.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 1 Belhaven-terrace, Glasgow.
1870.§§Blackmore, W. Founder's Court, Lothbury, London, E.C.
*Blackwall, Rev. John, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1863. ‡Bladen, Charles. Jarrow Iron Company, Newcastle-on-Tyne.
1863. ‡Blake, C. Carter, Ph.D., F.G.S. 170 South Lambeth-road, London, S.W.

Year of
Election.

1849 *Blake, Henry Wollaston, M.A., F.R.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1845. ‡Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.
1861. §§Blakiston, Matthew. Mobberley, Knutsford.
*Blakiston, Peyton, M.D., F.R.S. Warrior-square, St. Leonard's-on-Sea.
1868. ‡Blanc, Henry, M.D. 9 Bedford-street, Bedford-square, London, W.C.
1869. ‡Blandford, W. T., F.G.S., Geological Survey of India, Calcutta. (12 Keppel-street, Russell-square, London, W.C.)
Blanshard, William. Redcar.
Blore, Edward, F.S.A. 4 Manchester-square, London, W.
1870. §§Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1850. ‡Blyth, John, M.D., Professor of Chemistry in Queen's College, Cork.
1858. *Blythe, William. Holland Bank, near Accrington.
1870. §§Boardman, Edward. Queen-street, Norwich.
Boase, Charles W. 25 Drummond-place, Edinburgh.
1845. ‡Bodmer, Rodolphe. Newport, Monmouthshire.
1864. ‡Bogg, J. Louth, Lincolnshire.
1866. §Bogg, Thomas Wemyss. Louth, Lincolnshire.
1859. *Bohn, Henry G., F.L.S., F.R.A.S., F.R.G.S. North End House, Twickenham, London, S.W.
1871. §Bohn, Mrs. North-end House, Twickenham.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
1863. ‡Bond, Francis T., M.D. Hartley Institution, Southampton.
Bond, Henry John Hayes, M.D. Cambridge.
1871. §Bonney, Rev. Thomas George, M.A., F.S.A., F.G.S. St. John's College, Cambridge.
Bonomi, Ignatius. 36 Blandford-square, London, N.W.
Bonomi, Joseph. Soane's Museum, 15 Lincoln's-Inn-fields, London, W.C.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1835. ‡Booth, Rev. James, LL.D., F.R.S., F.R.A.S. The Vicarage, Stone, near Aylesbury.
1861. *Booth, John. Greenbank, Monton, near Manchester.
1861. *Booth, William. Holybank, Cornbrook, Manchester.
1861. *Borchardt, Dr. Louis. Oxford Chambers, Oxford-street, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1863. ‡Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
*Bossey, Francis, M.D. Oxford-road, Red Hill, Surrey.
Bosworth, Rev. Joseph, LL.D., F.R.S., F.S.A., M.R.I.A., Professor of Anglo-Saxon in the University of Oxford. Oxford.
1867. §Botly, William, F.S.A. Salisbury Villa, Hamlet-road, Upper Norwood, London, S.E.
1858. ‡Botterill, John. Burley, near Leeds.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. §Bottomley, James Thomson, M.A., F.C.S. The College, Glasgow.
Bottomley, William. Forbreda, Belfast.
1850. ‡Bouch, Thomas, C.E. Oxford-terrace, Edinburgh.
1870. §§Boult, Swinton. 1 Dale-street, Liverpool.

Year of
Election.

Bourne, Lieut.-Colonel J. D.
1866.§§Bourne, Stephen. Abberley Lodge, Hudstone-drive, Harrow, N.W.
1858. ‡Bousfield, Charles. Roundhay, near Leeds.
1868. ‡Boulton, W. S. Norwich.
1870. §Bower, Anthony. Bowerdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1846. *Bowerbank, James Scott, LL.D., F.R.S., F.G.S., F.L.S., F.R.A.S. 2 East Ascent, St. Leonard's-on-Sea.
1856. *Bowlby, Miss F. E. 27 Lansdown-crescent, Cheltenham.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S. 5 Clifford-street, London, W.
1869. §Bowring, Charles T. Elmsleigh, Princes' Park, Liverpool.
‡Bowring, Sir John, LL.D., F.R.S. Athenæum Club, Pall Mall, London, S.W.; and Claremont, Exeter.
1869. ‡Bowring, J. C. Larkbeare, Exeter.
1863. ‡Bowron, James. South Stockton-on-Tees.
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
1871. §Boyd, Thomas J. 41 Moray-place, Edinburgh.
Boyle, Alexander, M.R.I.A. 35 College Green, Dublin.
1865. ‡Boyle, Rev. G. D. Soho House, Handsworth, Birmingham.
Brabant, R. H., M.D. Bath.
1869. *Braby, Frederick, F.G.S., F.C.S. Mount Henley, Sydenham Hill, S.E.
1870. §Brace, Edmund. 17 Water-street, Liverpool.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1861. *Bradshaw, William. 35 Mosley-street, Manchester.
1842. *Brady, Sir Antonio, F.G.S. Maryland Point, Stratford, Essex.
1857. *Brady, Cheyne, M.R.I.A. Four Courts, Co. Dublin.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡Brady, George S. 22 Fawcett-street, Sunderland.
1862.§§Brady, Henry Bowman, F.L.S., F.G.S. 40 Mosley-street, Newcastle-on-Tyne.
1858. ‡Brae, Andrew Edmund. 29 Park-square, Leeds.
1864. §Braham, Philip. 6 George-street, Bath.
1870.§§Braidwood, Dr. Delemere Terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1865. §Bramwell, Frederick J., C.E. 37 Great George-street, London, S.W.
Brancker, Rev. Thomas, M.A. Limington, Somerset.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Henry. Dickleborough Rectory, Scole, Norfolk.
1852. ‡Brazier, James S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *Breadalbane, The Right Hon. Earl of. Taymouth Castle, N. B.; and Carlton Club, Pall Mall, London, S.W.
1859. ‡Brebner, Alexander C. Audit Office, Somerset House, London, W.C.
1859. *Brebner, James. Moss Villa, Elgin, N.B.
1867. ‡Brechin, The Right Rev. Alexander Penrose Forbes, Lord Bishop of, D.C.L. Castlehill, Dundee.
1868. §Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1869. ‡Brent, Colonel Robert. Woodbury, Exeter.
1860. ‡Brett, G. Salford.
1854. **Brett, Henry Watkins.*
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1865. §Brewin, William. Cirencester.
1867.§§Bridgman, William Kenceley. 69 St. Giles's-street, Norwich.

Year of
Election.

1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. §Brierley, Joseph, C.E. Blackburn.
1866. *Briggs, Arthur. Craig Royd, Rawden, near Leeds.
*Briggs, General John, F.R.S., M.R.A.S., F.G.S. 2 Tenterden-street, London, W.
1870. *Brigg, John. Keighley, Yorkshire.
1866. §Briggs, Joseph. Ulverstone, Lancashire.
1863. *Bright, Sir Charles Tilston, C.E., F.G.S., F.R.G.S., F.R.A.S. 69 Lancaster Gate, W.; and 6 Westminster Chambers, Victoria-street, London, S.W.
1870. §§Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
Bright, The Right Hon. John, M.P. Rochdale, Lancashire.
1868. ‡Brine, Commander Lindesay. Army and Navy Club, Pall Mall, London, S.W.
1863. ‡*Brivit, Henri.*
1842. Broadbent, Thomas. Marsden-square, Manchester.
1859. ‡Brodhurst, Bernard Edwin. 20 Grosvenor-street, Grosvenor-square, London, W.
1847. ‡Brodie, Sir Benjamin C., Bart., M.A., F.R.S., Professor of Chemistry in the University of Oxford. Cowley House, Oxford.
1834. ‡Brodie, Rev. James, F.G.S. Monimail, Fifeshire.
1865. ‡Brodie, Rev. Peter Bellenger, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
Bromilow, Henry G. Merton Bank, Southport, Lancashire.
*Brooke, Charles, M.A., F.R.S. 16 Fitzroy-square, London, W.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Drewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1863. §Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawstenstall, Manchester.
Brooks, William. Ordfall-hill, East Retford, Nottinghamshire.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1863. *Brough, Lionel H., F.G.S., one of Her Majesty's Inspectors of Coal-Mines. 11 West Mall, Clifton, Bristol.
1867. §§Brough, John Cargill. London Institution, Finsbury Circus, London, E.C.
*Broun, John Allan, F.R.S., Late Astronomer to His Highness the Rajah of Travancore.
1869. ‡Brown, Mrs. 1 Stratton-street, Piccadilly, London, W.
1863. *Brown, Alexander Crum, M.D., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinbugh. 8 Belgrave-crescent, Edinburgh.
Brown, Charles Edward.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 3 Mansfield-place, Glasgow.
1871. §Brown, David. 17 S. Norton-place, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1865. §Brown, Edwin, F.G.S. Burton-upon-Trent.
1858. §Brown, Alderman Henry. Bradford.
1870. §Brown, Horace T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1858. ‡*Brown, John. Barnsley.*
1870. §Brown, J. Campbell, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1859. ‡Brown, John Crombie, LL.D., F.L.S. Haddington, Scotland.
1863. ‡Brown, John H. 29 Sandhill, Newcastle-on-Tyne.

Year of Election.

1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. §Brown, Robert, M.A., Ph.D., F.R.G.S. 4 Gladstone-terrace, Edinburgh.
1856. *Brown, Samuel, F.S.S., F.R.G.S. The Elms, 42 Larkhall Rise, Clapham, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Lower Hardwick, Chepstow.
*Brown, William. 11 Maiden-terrace, York-road, Upper Holloway, London, N.
1855. ‡Brown, William. 11 Albany-place, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41 *a* New-street, Birmingham.
1863. ‡*Browne, B. Chapman. Tynemouth.*
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. §Browning, John, F.R.A.S. 111 Minories, London, E.
1855. §Brownlee, James, Jun. 273 St. George's-road, Glasgow.
Brownlie, Archibald. Glasgow.
1853. ‡Brownlow, William B. Villa-place, Hull.
1852. ‡Bruce, Rev. William. Belfast.
1863. *Brunel, H. M. 18 Duke-street, Westminster, S.W.
1863. ‡Brunel, J. 18 Duke-street, Westminster, S.W.
1871. §Brunnöw, F. Dunsink, Dublin.
1868. §Brunton, T. L. 23 Davies-street, London, W.
1859. ‡*Bryant, Arthur C.*
1861. ‡Bryce, James. York Place, Higher Broughton, Manchester.
Bryce, James, M.A., LL.D., F.R.S.E., F.G.S. High School, Glasgow, and Bowes Hill, Blantyre, by Glasgow.
Bryce, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. §§Buccleuch and Queensberry, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.S.L. Whitehall Gardens, London, S.W.; and Dalkeith Palace, Edinburgh.
1871. §Buchan, Alexander. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
Buchanan, Andrew, M.D. Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton cum Seacombe, Cheshire.
1871. §Buchanan, John Y. 10 Moray-place, Edinburgh.
*Buck, George Watson. Ramsay, Isle of Man.
1864. §Buckle, Rev. George, M.A. Twerton Vicarage, Bath.
1865. *Buckley, Henry. 29 Calthorpe-street, Edgbaston, Birmingham.
1848. *Buckman, James, F.L.S., F.G.S. Bradford Abbas, Sherbourne, Dorsetshire.
1869. ‡Bucknill, J. Hillmorton Hall, Rugby.
1851. *Buckton, George Bowdler, F.R.S., F.L.S. Weycombe, Haslemere, Surrey.
1848. *Budd, James Palmer. Ystalyfera Iron Works, Swansea.
1871. §Bullock, Matthew. 11 Park-circus, Glasgow.
1845. *Bunbury, Sir Charles James Fox, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1845. ‡Bunbury, Edward H., M.A., F.G.S. 35 St. James's-street, London, S.W.
1865. ‡Bunce, John Mackray. 'Journal Office,' New-street, Birmingham.
Bunch, Rev. Robert James, B.D. Emanuel Rectory, Loughborough.

Year of
Election.

1863. §Bunning, T. Wood. 34 Grey-street, Newcastle-on-Tyne.
Bunt, Thomas G. Nugent-place, Bristol.
1842. *Burd, John. 37 Jewin-street, Aldersgate-street, London, E.C.
1869. ‡Burdett-Coutts, Baroness. Stratton-street, Piccadilly, London, W.
Burgoyne, Sir John F., Bart., G.C.B., Field Marshal, D.C.L., F.R.S. 8 Gloucester-gardens, London, W.
1857. ‡Burk, J. Lardner, LL.D. 2 North Great George-street, Dublin.
1865. ‡Burke, Luke. 5 Albert-terrace, Acton, London, W.
1869. *Burnell, Arthur Coke. Sidmouth, South Devon.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1866. *Burton, Frederick M. Highfield, Gainsborough.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *Busk, George, F.R.S., V.P. L.S., F.G.S., Examiner in Comparative Anatomy in the University of London. 32 Harley-street, Cavendish-square, London, W.
1857. ‡Butt, Isaac, Q.C., M.P. 4 Henrietta-street, Dublin.
1855. *Buttery, Alexander W. Monkland Iron and Steel Company, Cardarroch, near Airdrie.
1870. §§Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
Buxton, Edward North.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1854. ‡Byerley, Isaac, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. Orwell Works House, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh, Armagh.

Cabbell, Benjamin Bond, M.A., F.R.S., F.S.A., F.R.G.S. 1 Brick-court, Temple, E.C.; and 52 Portland-place, London, W.
1858. §Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. The Fell, Gateshead.
1854. §Caine, Nathaniel. Broughton Hall, Broughton-in-Furness.
1858. *Caine, Rev. William, M.A. Albert Park, Didsbury, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. Finnart on Loch Long, by Helensburgh, Glasgow.
1855. *Caird, James T. Greenock.
1857. ‡Cairnes, Professor.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1842. Callender, W. R. The Elms, Didsbury, Manchester.
1853. ‡Calver, E. K., R.N. 21 Norfolk-street, Sunderland.
1857. ‡Cameron, Charles A., M.D. 17 Ely-place, Dublin.
1870. §§Cameron, John, M.D. 17 Rodney-street, Liverpool.
1859. ‡Campbell, Rev. C. P., Principal of King's College, Aberdeen.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, E.C.
1855. ‡Campbell, Dugald, M.D. 186 Sauchiehall-street, Glasgow.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
*Campbell, Sir James. 29 Ingram-street, Glasgow.
Campbell, John Archibald, F.R.S.E. Albyn-place, Edinburgh.
1852. ‡*Campbell, William. Donegal-Square West, Belfast.*
1859. ‡Campbell, William. Dunmore, Argyllshire.

Year of
Election.

1871. §Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana.
1862. *Campion, Rev. William M. Queen's College, Cambridge.
1853. ‡Camps, William, M.D., F.L.S., F.R.G.S. 84 Park-street, Grosvenor-square, London, W.
1868. *Cann, William. 9 Southernhay, Exeter.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
Carlisle, Harvey Goodwin, D.D., Lord Bishop of. Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. §Carmichael, George. 11 Dudhope-terrace, Dundee.
Carmichael, H. 18 Hume-street, Dublin.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
1871. §Carpenter, Herbert P. 56 Regent's Park-road, London, N.W.
*Carpenter, Philip Pearsall, B.A., Ph.D. Montreal, Canada.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡Carpenter, William B., M.D., F.R.S., F.L.S., F.G.S., PRESIDENT ELECT, Registrar of the University of London. 56 Regent's Park Road, London, N.W.
1871. §Carpenter, W. Brunswick-square, Brighton.
1842. *Carr, William, M.D., F.L.S., F.R.C.S. Lee Grove, Blackheath, S.E.
1861. *Carrick, Thomas. 5 Clarence-street, Manchester.
1867. §Carruthers, William, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡Carte, Alexander, M.D. Royal Dublin Society, Dublin.
1868. §Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1870. §Carter, Dr. William. 69 Elizabeth-street, Liverpool.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E. Long Carr, Barnsley, Yorkshire.
*Cartmell, Rev. James, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
Cartmell, Joseph, M.D. Carlisle.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1870. §Cartwright, Joseph. 70 King-street, Dunkinfield.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. South Grove, Highgate, London, N.
1871. §Cash, Joseph. Bird Grove, Coventry.
1842. *Cassels, Rev. Andrew, M.A. Batley, near Leeds.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1866. ‡Catton, Alfred R., M.A., F.R.S.E. Dundonnell House, Dingwall, N.B.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §Cayley, Arthur, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. §Cecil, Lord Sackville. Holwood, Beckenham, Kent.
1870. §§Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. 35 Park-square, Leeds.
1860. §§Chadwick, David, M.P. 27 Belzize Park, London, N.W.
1842. Chadwick, Edwin, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston-court, near Leominster.

Year of Election.

1842. Chadwick, John. Broadfield, Rochdale.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*Challis, Rev. James, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 13 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡Chamberlain, J. H. Christ Church-buildings, Birmingham.
1868. ‡Chamberlin, Robert. Catton, Norwich.
1842. Chambers, George. High Green, Sheffield.
Chambers, John. Ridgefield, Manchester.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. The Mount, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James Simmers. Handsworth, Birmingham.
1865. §Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.C.S. Frewen Hall, Oxford.
1850. ‡Chapman, Prof. E. J. 4 Addison-terrace, Kensington, London, W.
1866. ‡Chapman, Ernest T., F.C.S. 21 London-villas, Devonport-road, Shepherd's Bush, London, W.
1861. *Chapman, John. Hill End Mottram, Manchester.
1866. ‡Chapman, William. The Park, Nottingham.
1871. §Chappell, William, F.S.A. Heather Down, Ascot, Berks.
1854. ‡*Chapple, Frederick.*
1871. §Charles, T. C., M.D. Queen's College, Belfast.
1836. Charlesworth, Edward, F.G.S. Museum, Norwich.
1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1863. ‡*Charlton, F.*
1866. ‡Charnock, Richard Stephen, Ph.D., F.S.A., F.R.G.S. 8 Gray's Inn-square, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 6 Hyde Park-place, Cumberland Gate, London, W.
1842. *Cheetham, David. 12 Camden-crescent, Bath.
1853. *Chesney, Major-General Francis Rawdon, R.A., D.C.L., F.R.S., F.R.G.S. Ballyardle, Newry, Kilkeel, Co. Down.
*Chevallier, Rev. Temple, B.D., F.R.A.S., Professor of Mathematics and Astronomy in the University of Durham. The College, Durham.
1865. §Child, Gilbert W., M.A., M.D., F.L.S. Elmhurst, Great Missenden, Bucks.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
Christison, Sir Robert, Bart., M.D., D.C.L., F.R.S. L. & E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1870. §Church, A. H., F.C.S., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1860. ‡Church, William Selby, M.A. 1 Harcourt Buildings, Temple, London, E.C.
1857. ‡Churchill, F., M.D. 15 Stephen's Green, Dublin.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.

Year of
Election.

1855. §Clapham, Robert Calvert. Wincomblee, Walker, Newcastle-on-Tyne.
1858. ‡Clapham, Samuel. 17 Park-place, Leeds.
1869. §Clapp, Frederick. Iser Cottege, Windlesham, Farnborough Station.
1857. ‡Clarendon, Frederick Villiers. 11 Blessington-street, Dublin.
**Clark, Rev. Charles, M.A.*
Clark, Courtney K. Haugh End, Halifax.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
Clark, G. T. Bombay; and Athenæum Club, London, S.W.
1846. *Clark, Henry, M.D. 4 Upper Moira-place, Southampton.
1861. ‡Clark, Latimer. 5 Westminster Chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
Clarke, George. Mosley-street, Manchester.
1861. *Clarke, J. H. 5 Shakespeare-street, Ardwick, Manchester.
1842. Clarke, Joseph. Waddington Glebe, Lincoln.
1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Lieut.-Col. William. Park-hill House, The Dingle, Liverpool.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1857. *Clayton, David Shaw. Norbury, Stockport, Cheshire.
1850. ‡Cleghorn, Hugh, M.D., F.L.S., late Conservator of Forests, Madras. Stravithy, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1861. §Cleland, John, M.D., Professor of Anatomy and Physiology in Queen's College, Galway.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
Clerke, Rev. C. C., D.D., Archdeacon of Oxford and Canon of Christ Church, Oxford. Milton Rectory, Abingdon, Berkshire.
1852. ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1869. §Clifford, Professor William Kingdon, M.A., University College; and 14 Maryland-road, Harrow-road, London, W.
1865. ‡Clift, John E., C.E. Redditch, Bromsgrove, near Birmingham.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866. §Close, Thomas, F.S.A. St. James's-street, Nottingham.
Clough, Rev. Alfred B., B.D. Brandeston, Northamptonshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1863. §Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. South Bank, Weston, near Bath.
1851. *Cobbold, John Chevallier, M.P. Holywells, Ipswich; and Athenæum Club, London, S.W.
1864. §§Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Lecturer on Zoology and Comparative Anatomy at the Middlesex Hospital. 84 Wimpole-street, Cavendish-square, London, W.
1854. ‡Cockey, William. 38 Burnbank Gardens, Glasgow.

Year of Election.

1861. *Coe, Rev. Charles C. Seymour House, Seymour-street, Leicester.
1864. *Cochrane, James Henry. Woodside, Carrigrohane, Co. Cork.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1853. ‡Colchester, William, F.G.S. Grundesburgh Hall, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1859. ‡Cole, Edward. 11 Hyde Park-square, London, W.
1859. *Cole, Henry Warwick, Q.C. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1860. ‡Coleman, J. J., F.C.S. Jeeswood Hall, Mold, North Wales.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's Green, Dublin.
1861. *Collie, Alexander. 12 Kensington Palace Gardens, London, W.
1869. §Collier, W. F. Woodtown, Horrabridge, South Devon.
1861. ‡*Collinge, John.*
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. Fair Mile, Henley-on-Thames.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Society, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
Collis, Stephen Edward. Listowel, Ireland.
1868. *Colman, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. §Coltart, Robert. Devonshire-road, Prince's Park, Liverpool.
Colthurst, John. Clifton, Bristol.
1869. ‡*Colvill, W. H.*
1865. *Combe, Thomas, M.A. Clarendon Press, Oxford.
*Compton, The Rev. Lord Alwyn. Castle Ashby, Northamptonshire.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Sea-court, Bangor, Co. Down, Ireland.
1864. *Conwell, Eugene Alfred, M.R.I.A. Trim, Co. Meath, Ireland.
1859. ‡*Cook, E. R.*
1861. **Cook, Henry.*
1863. ‡Cooke, Edward William, R.A., F.R.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868. ‡Cooke, Rev. George H. The Parsonage, Thorpe, Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish Road, Birkenhead.
1868. §Cooke, M. C, M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. Telegraph Office, Lothbury, London, E.C.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1862. *Cookson, Rev. H. W., D.D. St. Peter's College Lodge, Cambridge.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin. Mile Ash, Derby.
1850. ‡Cooper, Sir Henry, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge Villas, Bayswater, London, W.
1868. ‡Cooper, W. J. 28 Duke-street, Westminster, S.W.
1846. ‡Cooper, William White. 19 Berkeley-square, London, W.
1871. §Copeland, Ralph, Ph.D. Parsonstown, Ireland.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.
1842. *Corbet, Richard. Headington-hill, Oxford.

Year of Election.

1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
1870. *Corfield, W. H., M.A., M.B., F.G.S., Professor of Hygiène and Public Health in University College, London, W.C.
Cormack, John Rose, M.D., F.R.S.E. 5 Bedford-square, London, W.C.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazennose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Grahamstown.
1864. §Cotton, General Frederick C. Athenæum Club, Pall Mall, London, S.W.
1869. ‡Cotton, William. Pennsylvania, Exeter.
*Cotton, Rev. William Charles, M.A. Vicarage, Frodsham, Cheshire.
1865. ‡Courtald, Samuel, F.R.A.S. 76 Lancaster Gate, London; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
Cowie, Rev. Benjamin Morgan, M.A. 42 Upper Harley-street, Cavendish-square, London, W.
1871. §Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Clement Park, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
Cox, Robert. 25 Rutland-street, Edinburgh.
1867. *Cox, Thomas Hunter. 1 Meadow-place, Dundee.
1866. §Cox, William. 50 Newhall-street, Birmingham.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1871. §Cox, William J. 2 Vanburgh-place, Leith.
1854. §Crace-Calvert, Frederick, Ph.D., F.R.S., F.C.S., Honorary Professor of Chemistry to the Manchester Royal Institution. Royal Institute, Manchester.
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1859. ‡Craig, S. Clayhill, Enfield, Middlesex.
1857. ‡Crampton, Rev. Josiah., M.R.I.A. The Rectory, Florence-court, Co. Fermanagh, Ireland.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1857. ‡*Crawford, George Arthur, M.A.*
1871. *Crawford, William Caldwell. Eagle Foundry, Port Dundas, Glasgow.
1871. §Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cyfartha Castle, Merthyr Tydvil.
1871. §Cressley, Herbert. Broomfield, Halifax.
Creyke, The Venerable Archdeacon. Beeford Rectory, Driffield.
*Crichton, William. 17 India-street, Glasgow.
1865. ‡Crocker, Edwin, F.C.S. 76 Hungerford Road, Holloway, London, N.
Croft, Rev. John, M.A., F.C.P.S.
1858. ‡Crofts, John. Hillary-place, Leeds.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.

Year of Election.

1855. ‡Crompton, Charles, M.A. 22 Hyde Park-square, London, W.
*Crompton, Rev. Joseph, M.A. Bracondale, Norwich.
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
1870. §Crookes, Joseph. Brook Green, Hammersmith, London.
1865. §Crookes, William, F.R.S., F.C.S. 20 Mornington-road, Regent's Park, London, N.W.
1855. ‡Cropper, Rev. John. Wareham, Dosetshire.
1870. §§Crosfield, C. J. 5 Alexander Drive, Princes Park, Liverpool.
1870. *Crosfield, William, jun. 5 Alexander Drive, Prince's Park, Liverpool.
1870. §§Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §§Crosskey, Rev. H. W., F.G.S. 28 George Street, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward. Park Road, Halifax.
1866. *Crossley, Louis J., F.M.S. Willow Hall, near Halifax.
1865. ‡Crotch, George Robert. 19 Trumpington-street, Cambridge.
1861. §Crowley, Henry. Smedley New Hall, Cheetham, Manchester.
1863. §Crowther, Benjamin. Wakefield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1859. ‡Crum, James. Busby, Glasgow.
1851. ‡Cull, Richard, F.R.S., F.R.G.S. 13 Tavistock-street, Bedford-square, London, W.C.
Culley, Robert. Bank of Ireland, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1861. *Cunliffe, Edward Thomas. Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Handforth, Manchester.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. §Cunningham, Professor Robert O., M.D. Queen's College, Belfast.
1855. ‡Cunningham, William A. Manchester and Liverpool District Bank, Manchester.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.S.A., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡Curtis, Professor Arthur Hill, LL.D. 6 Trinity College, Dublin.
1866. ‡Cusins, Rev. F. L. 26 Addison-street, Nottingham.
1834. *Cuthbert, John Richmond. 40 Chapel-street, Liverpool.
Cuthbertson, Allan. Glasgow.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, Dr. O. Newport, Dundee.
1867. ‡Dalgleish, W. Dundee.
1870. §§Dallinger, Rev. W. H. Greenfield-road, Stoneycroft, Liverpool.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
1859. ‡Dalrymple, Colonel. Troup, Scotland.
1867. *Dalrymple, Donald, M.D., M.P., F.R.G.S. Thorpe Lodge, Norwich.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.

Year of Election.

1859. ‡*Daly, Lieut.-Colonel H. D.*
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡Danby, T. W. Downing Collge, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1849. *Danson, Joseph, F.C.S. 6 Shaw-street, Liverpool.
Danson, William. 6 Shaw-street, Liverpool.
1859. ‡Darbishire, Charles James. Rivington, near Chorley, Lancashire
1861. *Darbishire, Robert Dukinfield, B.A., F.G.S. 26 George-street, Manchester.
1852. ‡*Darby, Rev. Jonathan L.*
Darwin, Charles R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E., and M.R.I.A., Down, near Bromley, Kent.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
Davey, Richard, F.G.S. Redruth, Cornwall.
1870. §§Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.
1871. §Davidson, David. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1868. ‡Davie, Rev. W. C. Cringleford, Norwich.
1863. ‡Davies, Griffith. 17 Cloudesley-street, Islington, London, N.
1870. §§Davies, Edward, F.C.S. Royal Institution, Liverpool.
Davies, John Birt, M.D. The Laurels, Edgbaston, Birmingham.
1842. Davies-Colley, Dr. Thomas. 40 Whitefriars, Chester.
1870. *Davis, A. S. Roundhay Vicarage, Leeds.
1864. §§Davis, Charles E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1856. *Davis, Sir John Francis, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, Westbury by Bristol.
1859. ‡Davis, J. Barnard, M.D., F.R.S., F.S.A. Shelton, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1864. §Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869 †Daw, R. M. Bedford-circus, Exeter.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
1859. ‡*Dawes, Captain (Adjutant R.A. Highlanders).*
Dawes, John Samuel, F.G.S. Smethwick House, near Birmingham.
1860. *Dawes, John T., jun. Smethwick Hall, Smethwick, near Birmingham.
1864. ‡Dawkins, W. Boyd, M.A., F.R.S., F.G.S. Birchview, Norman-road, Rusholme, Manchester.
1865. ‡Dawson, George, M.A. Shenstone, Lichfield.
*Dawson, Henry. 14 St. James's-road, Liverpool.
1855. ‡Dawson, John W., M.A., LL.D., F.R.S., Principal of M'Gill College, Montreal, Canada.
Dawson, John. Barley House, Exeter.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1865. ‡*Day, Edward Charles H.*
1871. §Day, St. John Vincent. 166 Buchanan-street, Glasgow.
1870. §Deacon, G. F. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1870. §Deacon, Henry Wade. King's College, London, W.C.
1859. ‡Dean, David. Banchory, Aberdeen.
1861. ‡Dean, Henry. Colne, Lancashire.
1854. §Deane, Henry, F.L.S. Clapham Common, London, S.W.
1870. *Deane, Rev. George, D.Sc., B.A., F.G.S. The Chestnuts, Moseley-road, Birmingham.

Year of Election.

*Deane, Sir Thomas. 26 Longford-terrace, Monkstown, Co. Dublin.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S. Lecturer on Chemistry at Guy's Hospital.
*De Grey and Ripon, George Frederick, Earl, D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1854. *De La Rue, Warren, D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. Cranford, Middlesex; and Reform Club, London, S.W.
1870. §§De Meshin, Thomas. 5 Fig Tree-court, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
Denison, Sir William Thomas, K.C.B., Col. R.E., F.R.S., F.R.G.S., East Brent, Weston-super-Mare, Somerset.
*Dent, Joseph. Ribston Hall, Wetherby.
Dent, William Yerbury. Royal Arsenal, Woolwich, S.E.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1856. *Derby, The Right Hon. The Earl of, LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.
1870. §§Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.
1868. §Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡Devon, The Right Hon. The Earl of. Powderham Castle, near Exeter.
*Devonshire, William, Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡Dewar, James. Chemical Laboratory, The University, Edinburgh.
1858. ‡Dibb, Thomas Townend. Little Woodhouse, Leeds.
1870. §§Dickens, Colonel C. H.
1852. ‡Dickie, George, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H. Kingweston, Somerton, Taunton; and 119 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1861. *Dickinson, William Leeson 1 St. James's-street, Manchester.
1867. §Dickson, Alexander, M.D., Professor of Botany in the University of Glasgow. The College, Glasgow.
1868. ‡Dickson, J. Thompson. 33 Harley-street, London, W.
1863. *Dickson, William, F.S.A., Clerk of the Peace for Northumberland. Alnwick, Northumberland.
1862. *Dilke, Sir Charles Wentworth, Bart., M.P. 76 Sloane-street, London, S.W.
1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwern, near Swansea.
1869. §Dingle, Edward. 19 King Street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1837. Dircks, Henry, C.E., LL.D., F.C.S. 48 Charing Cross, London, S.W.
1868. ‡Dittmar, W. The University, Edinburgh.
1853. ‡Dixon, Edward, M.Inst.C.E. Wilton House, Southampton.
1865. ‡Dixon, L. Hooton, Cheshire.
1861. ‡Dixon, W. Hepworth, F.S.A., F.R.G.S. 6 St. James's Terrace, London, N.W.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.

Year of Election.

1860. *Dobbs, Archibald Edward, M.A. Richmond-road, Ealing, Middlesex.
1864. *Dobson, William. Oakwood, Bathwick-hill, Bath.
Dockray, Benjamin. Lancaster.
1870. *Dodd, John. 9 Canning-place, Liverpool.
1857. ‡Dodds, Thomas W., C.E. Rotherham.
*Dodsworth, Benjamin. Burton Croft, York.
*Dodsworth, George. Clifton-grove, near York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn-hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
*Donisthorpe, George Edmund. Belvedere, Harrowgate, Yorkshire.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1871. §Donkin, Arthur Scott, M.D., Lecturer on Forensic Medicine at Durham University. Sunderland.
1861. ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *Donnelly, William, C.B., Registrar-General for Ireland. 5 Henrietta-street, Dublin.
1857. ‡Donovan, M., M.R.I.A. Clare-street, Dublin.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. §Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. *Doughty, C. Montagu. 5 Gloucester-place, Portman-square, London, W.
1855. §Dove, Hector. Rose Cottage, Trinity, near Edinburgh.
1870. §§Dowie, J. M. Walstones, West Kirby, Liverpool.
Downall, Rev. John. Okehampton, Devon.
1857. ‡Downing, S., LL.D., Professor of Civil Engineering in the University of Dublin. Dublin.
1865. *Dowson, E. Theodore. Geldestone, near Beccles, Suffolk.
1869. ‡Drake, Francis, F.G.S. Teign House, Hinckley, Leicester.
Drennan, William, M.R.I.A. 35 North Cumberland-street, Dublin.
1868. §Dresser, Henry E. The Firs, South Norwood, Surrey.
1869. §Drew, Joseph, F.G.S. Weymouth.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
Drummond, H. Home, F.R.S.E. Blair Drummond, Stirling.
1858. ‡Drummond, James. Greenock.
1859. ‡Drummond, Robert. 17 Stratton-street, London, W.
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1863. ‡Dryden, James. South Benwell, Northumberland.
1856. *Ducie, Henry John Reynolds Moreton, Earl of, F.R.S. 1 Belgrave-square, London, S.W.; and Tortworth-court, Wotton-under-Edge.
1870. §§Duckworth, Henry, F.L.S., F.G.S. 5 Cook-street, Liverpool.
1867. *Duff, Mounstuart Ephinstone Grant-, LL.B., M.P. 4 Queen's Gate-gardens, South Kensington, London, W.; and Eden, near Banff, Scotland.
1852. ‡Dufferin, The Rt. Hon. Lord. Highgate, London, N.; and Clandeboye, Belfast.
1859. *Duncan, Alexander. 7 Princes Gate, London.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 5 Highbury Hill, London, N.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. §Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
1867. §Duncan, Peter Martin, M.D., F.R.S., Sec. G.S., Professor of Geology in King's College, London. 40 Blessington-road, Lee, S.E.

Year of Election.

Dunlop, Alexander. Clober, Milngavie, near Glasgow.
1853. *Dunlop, William Henry. Annan-hill, Kilmarnock, Ayrshire.
1865. §Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1862. §Dunn, Robert, F.R.C.S. 31 Norfolk-street, Strand, London W.C.
Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall, York.
*Dunraven, Edwin, Earl of, F.R.S., F.R.A.S., F.G.S., F.R.G.S. Adare Manor, Co. Limerick; and Dunraven Castle, Glamorganshire.
1859. ‡Duns, Rev. John, F.R.S.E. 4 North Mansion House-road, Edinburgh.
1852. ‡Dunville, William. Richmond Lodge, Belfast.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Durnford, Rev. R. Middleton, Lancashire.
1857. ‡Dwyer, Henry L., M.A., M.B. 67 Upper Sackville-street, Dublin.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. §Dymond, Edward E. Oaklands, Aspland Guise, Woburn.
1870. §Dysdale, Dr. 36 A Rodney-street, Liverpool.

1868 ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1864. ‡Earle, Rev. A. Rectory, Monkton Farleigh, Bath.
Earle, Charles, F.G.S.
*Earnshaw, Rev. Samuel, M.A. Broomfield, Sheffield.
1871. *Easton, Edward. 23 Duke-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham
Eaton, Rev. George, M.A. The Pole, Northwich.
1870.§§Eaton, Richard. Nottingham.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1867. ‡Eckersley, James. Leith Walk, Edinburgh.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. North Laiths, Ollerton, Notts.
1870. *Eddison, John Edwin. Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
*Edgeworth, Michael P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.
1855. ‡Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 7 York-place, Northam, Southampton.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. §Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867.§§Edward, James. Balruddery, Dundee.
Edwards, John. Halifax.
1855. *Edwards, Professor J. Baker, Ph.D., D.C.L. Montreal, Canada.
1867.§§Edwards, William. 70 Princes-street, Dundee.
*Egerton, Sir Philip de Malpas Grey, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1855. ‡Elder, David. 19 Paterson-street, Glasgow.
1858. ‡Elder, John. Elm Park, Govan-road, Glasgow.
1868. §Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.

Year of Election.

Ellacombe, Rev. H. T., F.S.A. Clyst, St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1855. §Elliot, Robert. Wolfelee, Hawick, N. B.
1861. *Elliot, Sir Walter, K.S.I., F.L.S. Wolfelee, Hawick, N. B.
1864. ‡Elliott, E. B. Washington, United States.
1862. §§Elliott, Frederick Henry, M.A. 449 Strand, London, W.C.
Elliott, John Fogg. Elvet-hill, Durham.
1859. ‡Ellis, Henry S., F.R.A.S. Fair Park, Exeter.
1864. *Ellis, Alexander John, B.A., F.R.S. 25 Argyll-road, Kensington, London, W.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. §Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1869. §§Ellis, William Horton. Pennsylvania, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
Eltoft, William. Care of J. Thompson, Esq., 30 New Cannon-street, Manchester.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Brainhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1871. §Engelson, T. 11 Portland-terrace, Regent's Park, London, N.W.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. §English, J. T. Stratton, Cornwall.
Enniskillen, William Willoughby, Earl of, D.C.L., F.R.S., M.R.I.A., F.G.S. 26 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1869. ‡Ensor, Thomas. St. Leonards, Exeter.
1869. *Enys, John Davis. Canterbury, New Zealand. (Care of J. S. Enys, Esq., Enys, Penryn, Cornwall.)
*Enys, John Samuel, F.G.S. Enys, Penryn, Cornwall.
1864. *Eskrigge, R. A., F.G.S. Batavia-buildings, Liverpool.
1862. *Esson, William, M.A., F.R.S., F.C.S. Merton College, Oxford.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. §Etheridge, Robert, F.R.S.E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.
1870. *Evans, Arthur John. Nash Mills, Hemel Hempstead.
1865. *Evans, Rev. Charles, M.A. King Edward's School, Birmingham.
1849. *Evans, George Fabian, M.D. 14 Temple-row, Birmingham.
1848. ‡Evans, Griffith F. D., M.D. Trewern, near Welshpool, Montgomeryshire.
1869. *Evans, H. Saville W. 35 Hertford-street, May Fair, London, W.
1861. *Evans, John, F.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempstead.
1865. ‡Evans, Sebastian, M.A., LL.D. Highgate, near Birmingham.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.
Evanson, R. T., M.D. Holme Hurst, Torquay.
1871. §Eve, H. W. Wellington College, Wokingham, Berkshire.
1868. *Everett, J. D., D.C.L., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere Malone-road, Belfast.

Year of Election.

1863. *Everitt, George Allen, K.L., K.H., F.R.G.S. Knowle Hall, Warwickshire.
1859. *Ewing, Archibald Orr. Ballikinrain, Killearn, by Glasgow.
1855. *Ewing, William. 209 West George-street, Glasgow.
1871. *Exley, John T., M.A. Cotham, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, Knightsbridge, London; and Warren's, near Lyndhurst, Hants.
1866. ‡Eyre, Major-General Sir Vincent, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1842. Fairbairn, Thomas. Manchester.
*Fairbairn, Sir William, Bart., C.E., LL.D., F.R.S., F.G.S., F.R.G.S. Manchester.
1866. ‡*Fairbank, R. F., M.A.*
1865. ‡Fairley, Thomas. Chapel Allerton, Leeds.
1870. §Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
Fannin, John, M.A. 41 Grafton-street, Dublin.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1861. §Farr, William, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Registry Office. Southlands, Bickley, Kent.
1866. *Farrar, Rev. Frederick William, M.A., F.R.S. Marlborough.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulconer, R. S. Fairlawn, Clarence-road, Clapham Park, London.
1869. ‡Faulding, Joseph. 340 Euston-road, London, N.W.
1869. ‡Faulding, W. F. Didsbury College, Manchester.
1859. *Faulkner, Charles, F.S.A., F.G.S., F.R.G.S. Museum, Deddington, Oxon.
1859. *Fawcett, Henry, M.P., Professor of Political Economy in the University of Cambridge. 42 Bessborough-gardens, Pimlico, London, S.W.; and Trinity Hall, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1833. Fearon, John Peter. Cuckfield, Sussex.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverston, Lancashire.
1864. §Fellowes, Frank P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square, and Keswick, near Belfast.
1855. ‡Ferguson, James. Gas Coal-works, Lesmahago, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. §Ferguson, John. The College, Glasgow.
1855. ‡*Ferguson, Peter.*
1867. §Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Samuel. 20 North Great George-street, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. 2 St. Aiden's-terrace, Birkenhead.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *Fernie, John. 3 Moorland-terrace, Leeds.
1862. ‡Ferrers, Rev. N. M., M.A. Caius College, Cambridge.
1868. ‡Field, Edward. Norwich.
Field, Edwin W. 36 Lincoln's Inn Fields, London, W.C.
1869. *Field, Rogers. 6 Cannon-row, Westminster, S.W.
Fielding, G. H., M.D. Tunbridge, Kent.
1864. ‡Finch, Frederick George, B.A., F.G.S. Fern House, Myrtle-place, Blackheath, London, S.E.

Year of Election.

Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1859. ‡Findlay, Alexander George, F.R.G.S. 53 Fleet-street, London, E.C.; Dulwich Wood Park, Surrey.
1863. ‡Finney, Samuel. Sheriff-hill Hall, Newcastle-upon-Tyne.
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1851. *Fischer, William L. F., M.A., LL.D., F.R.S., Professor Mathematics in the University of St. Andrews, Scotland.
1858. ‡Fishbourne, Captain E. G., R.N. 6 Welamere-terrace, Paddington, London, W.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlston Rectory, near Cambridge.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W. Greenholme, Burley in Whaffdale, near Leeds.
1871. §Fitch, J. G., M.A. Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1857. ‡Fitzgerald, The Right Hon. Lord Otho, M.P. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
Fitzwilliam, Hon. George Wentworth, M.P., F.R.G.S. 19 Grosvenor-square, London, S.W.; and Wentworth House, Rotherham.
1865. ‡Fleetwood, D. J. 45 George Street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 20 Temple-row, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
Fleming, John G., M.D. 155 Bath-street, Glasgow.
*Fleming, William, M.D. Rowton Grange, near Chester.
1867. §Fletcher, Alfred E. 21 Overton-street, Liverpool.
1870. §Fletcher, B. Edgington. Norwich.
1853. ‡Fletcher, Isaac, F.R.S., F.G.S., F.R.A.S. Tarn Bank, Workington.
1869. §Fletcher, Lavington E., C.E. 41 Cooperation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡Flower, William Henry, F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's Inn-fields, London, W.C.
1866. ‡Flowers, John W., F.G.S. Park Hill, Croydon, Surrey.
1867. ‡Foggie, William. Woodville, Maryfield, Dundee.
1854. *Forbes, David, F.R.S., F.G.S., F.C.S. 11 York-place, Portman-square, London, W.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
1855. ‡Forbes, Rev. John, D.D. 150 West Regent-street, Glasgow.
Ford, H. R. Morecombe Lodge, Yealand Congers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park Gardens East, London, W.
*Forrest, William Hutton. The Terrace, Stirling.
1867. §Forster, Anthony. Newsham Grange, Winston, Darlington.
1849. *Forster, Thomas Emerson. 7 Ellison-place, Newcastle-upon-Tyne.
*Forster, William. Ballynure, Clones, Ireland.
1858. ‡Forster, William Edward. Burley, Otley, near Leeds.
1871. §Forsyth, William F. Denham Green, Trinity, Edinburgh.
1854. *Fort, Richard. 24 Queen's Gate-gardens, London, W.; and Read Hall, Whalley, Lancashire.
1870. §Forwood, William B. Hopeton House, Seaforth, Liverpool.
1865. ‡Foster, Balthazar W., M.D. 4 Old Square, Birmingham.

Year of Election.

1865. *Foster, Clement Le Neve, D.Sc., F.G.S. East Hill, Wandsworth, London, S.W.

1857. *Foster, George C., B.A., F.R.S., F.C.S., Professor of Experimental Physics in University College, London, W.C. 16 King Henry's-road, London, N.W.

*Foster, Rev. John, M.A. The Oaks Parsonage, Loughborough.

1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.

1859. *Foster, Michael, M.D., F.L.S. Trinity College, Cambridge.

1859. §Foster, Peter Le Neve, M.A. Society of Arts, Adelphi, London, W.C.

1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.

1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.

1842. Fothergill, Benjamin. 10 The Grove, Boltons, West Brompton, London.

1870. §§Foulger, Edward. 55 Kirkdale-road, Liverpool.

1866. §Fowler, George. 56 Clarendon Street, Nottingham.

1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.

1856. ‡Fowler, Rev. Hugh, M.A. College-gardens, Gloucester.

1870. *Fowler, Robert Nicholas, M.A., M.P., F.R.G.S. 36 Cavendish-square, London, W.

Fox, Alfred. Penjerrick, Falmouth.

1868. ‡Fox, Colonel A. Lane, F.G.S., F.S.A. 10 Upper Phillimore-gardens, Kensington, London, S.W.

1842. *Fox, Charles. Trebah, Falmouth.

*Fox, Rev. Edward, M.A. The Vicarage, Romford, Essex.

*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.

1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.

Fox, Robert Were, F.R.S. Falmouth.

1866. *Francis, G. B. 8 Nelson-terrace, Stoke Newington, London, N.

Francis, William, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and 1 Matson Villas, Marsh-gate, Richmond, Surrey.

1846. ‡Frankland, Edward, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster Gate, London. W.

*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.

Franks, Rev. J. C., M.A. Whittlesea, near Peterborough.

1859. ‡Fraser, George B. 3 Airlie-place, Dundee.

Fraser, James. 25 Westland-row, Dublin.

Fraser, James William. 8A Kensington Palace-gardens, London, W.

1865. *Fraser, John, M.A., M.D. Chapel Ash, Wolverhampton.

1871. §Fraser, Thomas R., M.D., F.R.S.E. Grosvenor-place, Edinburgh.

1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.

1871. §Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.

1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.

1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.

1871. §Freeman.

1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.

1869. §Frere, Sir Bartle, F.R.G.S. 22 Princes-gardens, London.

Frere, George Edward, F.R.S. Royden Hall, Diss, Norfolk.

1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.

Fripp, George D., M.D. Barnfield Hill, Southampton.

1857. *Frith, Richard Hastings, C.E. 48 Summer Hill, Dublin.

1863. *Frith, William. Burley Wood, near Leeds.

1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.

Year of Election.

Frost, Charles, F.S.A. Hull.
1860. *Froude, William, C.E., F.R.S. Chelston Cross, Torquay.
Fry, Francis. Cotham, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
Fry, Robert. Tockington, Gloucestershire.
1863. ‡Fryar, Mark. Eaton Moor Colliery, Newcastle-on-Tyne.
1859. ‡Fuller, Frederick, M.A., Professor of Mathematics in University and King's College, Aberdeen.
1869. §§Fuller, George, C.E., Professor of Engineering in University College, London. Argyll-road, Kensington, London, W.
1852. ‡Furguson, Professor John C., M.A., M.B. Queen's College, Belfast.
1864. *Furneaux, Rev. Alan. St. Germain's Parsonage, Cornwall.

*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Handsworth Grange, near Sheffield.
1850. ‡Gairdner, Professor W. F., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
Galbraith, Rev. J. A., M.R.I.A. Trinity College, Dublin.
1867. ‡Gale, James M. 33 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1859. ‡*Galloway, James. Calcutta.*
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
Galloway, S. H. Linbach, Austria.
1860. *Galton, Captain Douglas, C.B., R.E., F.R.S., F.L.S., F.G.S., F.R.G.S. (General Secretary.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *Galton, Francis, F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. §§Galton, John C., M.A., F.L.S. 13 Margaret-street, Cavendish-square, London, W.
1870. §Gamble, D. St. Helens, Lancashire.
1870. §§Gamble, J. C. St. Helens, Lancashire.
1868. ‡Gamgee, Arthur, M.D., F.R.S.E. 27 Alva-street, Edinburgh.
1862 §Garner, Robert, F.L.S. Stoke-upon-Trent.
1865. §Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1870. §§Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Woolton Wood, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1846. §Gassiot, John Peter, D.C.L., LL.D., F.R.S., F.C.S. Clapham Common, London, S.W.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinsted, Sussex.
1871. §Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M.A., Professor of Greek, King's College, Old Aberdeen.
1854. §§Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. §Geikie, Archibald, F.R.S., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh; and Ramsay Lodge, Edinburgh.
1871. §Geikie, James, F.R.S.E. 16 Duncan-terrace, Newington, Edinburgh.
1855. ‡Gemmell, Andrew. 38 Queen-street, Glasgow.
1854. §§Gerard, Henry. 18A Rumford-place, Liverpool.
1870. §Gerstl, R. University College, London, W.C.

Year of Election.

1870. *Gervis, Walter S., M.D. Ashburton, Devon.
1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
1863. *Gibb, Sir George Duncan, Bart., M.D., M.A., LL.D., F.G.S. 1 Bryanston-street, London, W.; and Falkland, Fife.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. §Gibson, Alexander. 19 Albany-street. Edinburgh.
1868. ‡Gibson, C. M. Bethel-street, Norwich.
*Gibson, George Stacey. Saffron Walden, Essex.
1852. ‡Gibson, James. 35 Mountjoy-square, Dublin.
1870.§§Gibson, R. E. Sankey Mills, Earlestown, near Newton-le-Willows.
1870.§§Gibson, Thomas. 51 Oxford-street, Liverpool.
1870.§§Gibson, Thomas, jun. 19 Parkfield-road, Princes Park, Liverpool.
1867. ‡Gibson, W. L., M.D. Tay-street, Dundee.
1842. Gilbert, Joseph Henry, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton Royal Institution, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *Gill, David, junr. 26 Silver-street, Aberdeen.
1868. ‡Gill, Joseph. Palermo, Scilly (care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.).
1864. ‡Gill, Thomas. 4 Sydney-place, Bath.
1861. *Gilroy, George. Hindley House, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1867. §Ginsburg, Rev. C. D., D.C.L., LL.D. Binfield, Bracknell, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1850. *Gladstone, George, F.C.S., F.R.G.S. Care of Henry Strut, Esq., Clapham Common, London, S.W.
1849. *Gladstone, John Hall, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1861. *Gladstone, Murray. Broughton House, Manchester.
1852. ‡*Gladstone, Thomas Murray.*
1861. *Glaisher, James, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, Kent.
1871. *Glaisher, J. W. L., F.R.A.S. Trinity College, Cambridge.
1853. ‡Gleadon, Thomas Ward. Moira-buildings, Hull.
1870. §Glen, David C. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London, W.C.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1870.§§Glynn, Thomas R. 1 Rodney-street, Liverpool.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1846. ‡Godwin-Austen, Robert A.C., B.A., F.R.S., F.G.S. Chilworth Manor, Guildford.
Goldsmid, Sir Francis Henry, Bart., M.P. St. John's Lodge, Regent's Park, London, N.W.
1842. *Gouch, Thomas L. Team Lodge, Saltwell, Gateshead.*
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870.§§Goodison, George William, C.E. Gateacre, Liverpool.
1842. *Goodman, John, M.D. Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869.§§Goodman, Neville. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Westhall Vicarage, Wangford.
1859. ‡*Gordon, H. G.*
1871. §Gordon, Joseph. Poynter's-row, Totteridge, Whetstone, London, N.
1870.§§Gordon, Rev. Alexander. 49 Upper Parliament-street, Liverpool.

Year of
Election.

1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870.§§Gossage, William. Winwood, Woolton, Liverpool.
*Gotch, Thomas Henry. Kettering.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Hon. G. S. Rathronan House, Clonmel.
1868. §Gould, Rev. George. Unthank-road, Norwich.
Gould, John, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.
1854. ‡Gourlay, Daniel De la C., M.D. Tollington Park, Hornsey-road, London, N.
1867. ‡Gourley, Henry (Engineer). Dundee.
Gowland, James. London-wall, London, E.C.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *Graham, Cyril, F.L.S., F.R.G.S. 9 Cleveland-row, St. James's, London, S.W.
Graham, Lieutenant David. Mecklewood, Stirlingshire.
1870.§§Graham, R. Hills. 4 Bentley-road, Princes Park, Liverpool.
1852. **Grainger, John.*
Grainger, Richard.
1871. §Grant, Sir Alexander, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1870.§§Grant, Colonel J. A., C.B., F.L.S., F.R.G.S. 7 Park-square West, London, N.W.
1859. ‡Grant, Hon. James. Cluny Cottage, Forres.
1855. *Grant, Robert, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1854. ‡Grantham, Richard B., C.E., F.G.S. 22 Whitehall-place, London, S.W.
Granville, Augustus Bozzi, M.D., F.R.S., M.R.I.A. 5 Cornwall-terrace, Warwick-square, Pimlico, London, S.W.
*Graves, Rev. Richard Hastings, D.D. Brigown Glebe House, Michelstown, Co. Cork.
1870.§§Gray, C. B. 5 Rumford-place, Liverpool.
1864. *Gray, Rev. Charles. The Vicarage, East Retford.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1857. ‡Gray, Sir John, M.D. Rathgar, Dublin.
**Gray, John.*
*Gray, John Edward, Ph.D., F.R.S., Keeper of the Zoological Collections of the British Museum. British Museum, London, W.C.
1864. ‡Gray, Jonathan. Summerhill-house, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870.§§Gray, T. Macfarlane. 12 Montenotte, Cork.
*Gray, William, F.G.S. Minster Yard, York.
1861. *Gray, Lt.-Colonel William, M.P. 26 Princes's-gardens, London, W.
1854. *Grazebrook, Henry, jun. Clent Grove, near Stourbidge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. Stafford-street, Derby.
1869. §Greaves, William. Wellington-circus, Nottingham.
Green, Rev. Henry, M.A. Heathfield, Knutsford, Cheshire.
*Greenaway, Edward. 91 Lansdowne-road, Notting Hill, London, W.
1858. *Greenhalgh, Thomas. Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.

Year of Election.

1862. *Greenwood, Henry. 32 Castle-street, and 37 Falkner-square, Liverpool.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Outwood Lodge, Prestwich, Manchester.
Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.
1861. §Gregson, Samuel Leigh. Aigburth-road, Liverpool.
Gresham, Thomas M. Raheny, Dublin.
*Greswell, Rev. Richard, B.D., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
Grey, Captain The Hon. Frederick William. Howick, Northumberland.
1869. ‡Grey, Sir George, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1866. ‡Grey, Rev. William Hewett C. North Sherwood, Nottingham.
1863. ‡Grey, W. S. Norton, Stockton-on-Tees.
1871. *Grierson, Samuel. Millholm House, Musselburgh, Edinburgh.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1870. §Grieve, John, M.D. 21 Lynedock-street, Glasgow.
*Griffin, John Joseph, F.C.S. 22 Garrick-street, London, W.C.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *Griffith, George, M.A., F.C.S. (Assistant General Secretary.) Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1868. ‡Griffith, Rev. John, M.A. The College, Brighton.
1870. §§Griffith, N. R. The Coppa, Mold, North Wales.
1870. §Griffith, Rev. Professor. Bowden, Cheshire.
*Griffith, Sir Richard John, Bart., LL.D., F.R.S.E., M.R.I.A., F.G.S. 2 Fitzwilliam-place, Dublin.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
Griffith, Walter H., M.A.
Griffiths, Rev. John, M.A. 63 St. Giles's, Oxford.
1870. §§Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1864. ‡Groom-Napier, Charles Ottley, F.G.S. 20 Maryland-road, Harrow-road, London, N.W.
1869. §Grote, Arthur. The Athenæum Club, Pall Mall, London, S.W.
Grove, William Robert, Q.C., M.A., Ph.D., F.R.S. 115 Harley-street, W; and 5 Crown Office-row, Temple, London, E.C.
1863. *Groves, Thomas B., F.C.S. 80 St. Mary's-street, Weymouth.
1869. ‡Grubb, Howard, F.R.A.S. Rathmines, Dublin.
1857. ‡Grubb, Thomas, F.R.S., M.R.I.A. 141 Leinster-road, Dublin.
Guest, Edwin, LL.D., M.A., F.R.S., F.L.S., F.R.A.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford-park, Oxfordshire.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College Green, Dublin.
1842. Guinness, Richard Seymour. 17 College Green, Dublin.
1856. *Guise, Sir William Vernon, Bart., F.G.S., F.L.S. Elmore-court, near Gloucester.
1862. ‡Gunn, Rev. John, M.A., F.G.S. Irstedd Rectory, Norwich.
1866. §§Günther, Albert C. L. G., M.D., F.R.S. British Museum, London, W.C.
1868. *Gurney, John. Earlham Hall, Norwich.

Year of Election.

1860. *Gurney, Samuel, M.P., F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.

*Gutch, John James. Blake-street, York.

1859. ‡Guthrie, Frederick, F.RS. Geological Museum, Jermyn-street, London, S.W.

1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.

1870.§§Guyton, Joseph. 23 Cathcart-road, West Brompton, London, S.W.

1857. ‡Gwynne, Rev. John. Tullyaguish, Letterkenny, Strabane, Ireland.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.

1865. §Hackney, William. Walter's-road, Swansea.

1865. ‡Haden, W. H. Cawney Bank Cottage, Dudley.

1866. *Hadden, Frederick J. The Park, Nottingham.

1862. ‡Haddon, Frederick William. 12 St. James's-square, London, S.W.

1866. ‡Haddon, Henry. Lenton Field, Nottingham.

Haden, G. N. Trowbridge, Wiltshire.

1842. Hadfield, George. Victoria-park, Manchester.

1870.§§Hadivan, Isaac. 3 Huskisson-street, Liverpool.

1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.

1870.§§Haigh, George. Waterloo, Liverpool.

*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.

1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.

1870.§§Halhead, W. B. 7 Parkfield-road, Liverpool.

Halifax, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.

1854. *Hall, Hugh Fergie. Greenheys, Wallasey, Birkenhead.

1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.

Hall, John R. Sutton, Surrey.

*Hall, Thomas B. Australia (care of J. P. Hall, Esq., Crane House, Great Yarmouth).

1866. *Hall, Townshend M., F.G.S. Pilton, Barnstaple.

1860. §Hall, Walter. 10 Pier-road, Erith.

1868. *Hallett, William Henry, F.L.S. The Manor House, Kemp Town, Brighton.

1861. ‡Halliday, James. Whalley Court, Whalley Range, Manchester.

1857. ‡Halpin, George, C.E. Rathgar, near Dublin.

Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.

Halswell, Edmund S., M.A.

1858. *Hambly, Charles Hambly Burbridge, F.G.S. 96 London-road, Leicester.

1866. §Hamilton, Archibald, F.G.S. South Barrow, Bromley, Kent.

1857. ‡Hamilton, Charles W. 40 Dominick-street, Dublin.

1865. §Hamilton, Gilbert. Leicester House, Kenilworth-road, Leamington.

Hamilton, The Very Rev. Henry Parr, Dean of Salisbury, M.A., F.R.S. L. & E., F.G.S., F.R.A.S. Salisbury.

1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.

1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.

1864. ‡*Hamilton, Rev. S. R., M.A.*

1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.

1871. §Hanbury, Daniel. Clapham-Common, London, S.W.

1863. ‡Hancock, Albany, F.L.S. 4 St. Mary's-terrace, Newcastle-upon-Tyne.

1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.

1850. ‡Hancock, John. Manor House, Lurgan, Co. Armagh.

1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London.

Year of Election.

1857. ‡Hancock, William J. 74 Lower Gardiner-street, Dublin.
1847. ‡Hancock, W. Nelson, LL.D. 74 Lower Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
Handyside, P. D., M.D., F.R.S.E. 11 Hope-street, Edinburgh.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*Harcourt, A. G. Vernon, M.A., F.R.S., F.C.S. Christ Church, Oxford.
Harcourt, Rev. C. G. Vernon, M.A. Rothbury, Northumberland.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Hill's Court, Exeter.
1869. ‡Harding, William D. Kings Lynn, Norfolk.
1864. §Hardwicke, Robert, F.L.S. 192 Piccadilly, London, W.
*Hare, Charles John, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
Harford, Summers. Haverfordwest.
1858. ‡Hargrave, James. Burley, near Leeds.
1853. §Harkness, Robert, F.R.S. L. & E., F.G.S., Professor of Geology in Queen's College, Cork.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1862. *Harley, George, M.D., F.R.S., Professor of Medical Jurisprudence in University College, London. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *Harley, Rev. Robert, F.R.S., F.R.A.S. Lancaster-place, Leicester.
1861. ‡Harman, H. W., C.E. 16 Booth-street, Manchester.
1868. *Harmer, F. W., F.G.S. Heigham Grove, Norwich.
*Harris, Alfred. Sleningford Park, near Ripon.
*Harris, Alfred, jun. Ashfield, Bingley, Yorkshire.
1863. ‡Harris, Charles. 6 Somerset-terrace, Newcastle-on-Tyne.
Harris, The Hon. and Right Rev. Charles, Lord Bishop of Gibraltar, F.G.S. Care of A. Martineau, Esq., 61 Westbourne-terrace, London, W.
1871. §Harris, George, F.S.A. Iselipps Manor, Middlesex.
*Harris, Henry. Longwood, near Bingley.
1863. ‡Harris, T. W. Grange, Middlesborough-on-Tees.
1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. §Harrison, George. Barnsley, Yorkshire.
1858. *Harrison, James Park, M.A. Garlands, Ewhurst, Surrey.
1870. §§Harrison, Reginald. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1853. *Harrison, William, F.S.A., F.G.S. Samlesbury Hall, near Preston, Lancashire.
1849. ‡Harrowby, The Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, S.W.; and Sandon Hall, Lichfield.
1859. *Hart, Charles. 54 Wych-street, Strand, London, W.C.
1861. *Harter, J. Collier. Chapel Walks, Manchester.
1842. *Harter, William. Hope Hall, Manchester.
1856. ‡Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Cheltenham.
Hartley, James. Sunderland.
1871. §Hartley, Walter Noel. King's College, London, W.C.

Year of
Election.

Hartly, J. B. Bootle, near Liverpool.
1854. §Hartnup, John, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870.§§Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea House, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-moors.
1855. ‡Hassall, Arthur Hill. 8 Bennett-street, St. James's, London, S.W.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
Haughton, James, M.R.D.S. 34 Eccles-street, Dublin.
1857. ‡Haughton, Rev. Samuel, M.D., M.A., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
1857. ‡*Haughton, S. Wilfred.*
*Haughton, William. 28 City Quay, Dublin.
Hawkins, John Heywood, M.A., F.R.S., F.G.S. Bignor Park, Petworth, Sussex.
**Hawkins, Thomas, F.G.S.*
*Hawkshaw, John, F.R.S., F.G.S. 43 Eaton-place, and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., F.G.S. 43 Eaton-place, London, W.
1868. §Hawksley, Thomas, C.E. 30 Great George-street, Westminster, S.W.
1853. ‡Haworth, Benjamin. Hull Bank House, near Hull.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1861. *Hay, Rear-Admiral Sir John C. D., Bart., M.P., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen Yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1869. ‡Hayward, J. High-street, Exeter.
1856. ‡Hayward, J. Curtis. Quedgeley, near Gloucester.
1858. *Hayward, Robert Baldwin, M.A. Harrow-on-the-hill.
1851. §Head, Jeremiah. Middlesborough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.
1861. *Heald, James. Parr's Wood, Didsbury, near Manchester.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1871. §Healey, George. Matson's, Windermere.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1865.§§Hearder, William. Victoria Parade, Torquay.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §Heathfield, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.
1865. ‡Heaton, Harry. Warstone, Birmingham.
1858. *Heaton, John Deakin, M.D. Claremont, Leeds.
1865. ‡Heaton, Ralph. Harborne Lodge, near Birmingham.
1833. ‡Heaviside, Rev. Canon J. W. L., M.A. The Close, Norwich.
1863. ‡*Heckels, Richard.*
1855. ‡Hector, James, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of Otago. Wellington, New Zealand.
1867.§§Heddle, M. Foster, M.D., Professor of Chemistry in the University of St. Andrew's, N. B.

Year of Election.

1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1862. ‡Helm, George F. 58 Trumpington-street, Cambridge.
1857. *Hemans, George William, C.E., M.R.I.A.. 1 Westminster Chambers, Victoria-street, London, S.W.
1867. ‡Henderson, Alexander. Dundee.
1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London.
1866. ‡Henderson, James, jun. Dundee.
1856. ‡Hennessy, Henry G., F.R.S., M.R.I.A. 86 St. Stephen's Green, Dublin.
1857. ‡Hennessy, John Pope. Inner Temple, London, E.C.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell. Stratheden House, Hyde Park, London, W.
*Henry, William Charles, M.D., F.R.S., F.G.S., F.R.G.S. Haffield, near Ledbury, Herefordshire.
1870. §§Henty, William. Norfolk-terrace, Brighton.
Henwood, William Jory, F.R.S., F.G.S. 3 Clarence-place, Penzance.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Sidcup-place, Sidcup, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1871. §Hepburn, Thomas H. St. Mary's Cray, Kent.
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
*Herbert, Thomas. The Park, Nottingham.
1852. ‡Herdman, John. 9 Wellington-place, Belfast.
1866. §§Herrick, Perry. Bean Manor Park, Loughborough.
1871. *Herschel, Professor Alexander S., B.A. College of Science, Newcastle-on-Tyne.
1865. ‡Heslop, Dr. Birmingham.
1863. ‡Heslop, Joseph. Pilgrim-street, Newcastle-on-Tyne.
1832. ‡Hewitson, William C. Oatlands, Surrey.
Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1861. *Heywood, Arthur Henry. The How, Prestwich, Manchester.
*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S. 26 Palace-gardens, Kensington, London, W.
1861 *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1854. ‡*Heyworth, Captain L., jun.*
1870. *Heyworth, Lawrence. Yewtree, Liverpool.
1864. *Hiern, W. P., M.A. 1 Foxton-villa, Richmond, Surrey.
1854. *Higgin, Edward.
1861. *Higgin, James. 5 Hopwood-avenue, Manchester.
Higginbotham, Samuel. 4 Springfield Court, Queen-street, Glasgow.
1866. ‡Higginbottom, John. Nottingham.
1871. §Higgins, Clement, F.C.S. 27 St. John's Park, Upper Holloway, London, N.
1861. ‡Higgins, George. Mount House, Higher Broughton, Manchester.
1854. ‡Higgins, Rev. Henry H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Stocks House, Cheetham, Manchester.
1870. §§Higginson, Alfred. 44 Upper Parliament-street, Liverpool.
1842. *Higson, Peter, F.G.S., H.M. Inspector of Mines. The Brooklands, Swinton, near Manchester.
1870. §Highton, Rev. H. 2 The Cedars, Putney, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.

Year of Election.

1862. *Hiley, Rev. Simeon. Elland, near Halifax.
Hill, Arthur. Bruce Castle, Tottenham, London, N.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. ‡Hill, John. Tullamore, Ireland.
1871. §Hill, Lawrence. The Knowe, Greenock.
*Hill, Sir Rowland, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.
1864. ‡Hill, William. Combe Hay, Bristol.
1863 ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡Hincks, Rev. Thomas, B.A. Mountside, Leeds.
1870.§§Hinde, G. J. Buenos Ayres.
Hindley, Rev. H. J. Edlington, Lincolnshire.
1852. *Hindmarsh, Frederick, F.G.S., F.R.G S. 4 New Inn, Strand, London, W.C.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. *Hinmers, William. Cleveland House, Birkdale, Southport.
1858.§§Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, T. Archer, Ph.D., F.R.S, F.R.A.S. The University of London, Burlington Gardens, W., and Athenæum Club, Pall Mall, London, S.W.
1856. ‡Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.
1860. ‡Hitchman, John. Leamington.
1870.§§Hitchman, William, M.D. 29 Erskine-street, Liverpool.
*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1863. §Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green, London, W.
1866. ‡Hockin, Charles, M.D. 8 Avenue-road, St. John's Wood, London.
1852. ‡Hodges, John F., M.D., Professor of Agriculture in Queen's College, Belfast. 23 Queen-street, Belfast.
1863. *Hodgkin, Thomas. Benwell Dene, Newcastle-on-Tyne.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
Hodgson, Thomas. Market-street, York.
1839. ‡Hodgson, W. B., LL.D., F.R.A.S. 41 Grove End-road, St. John's Wood, London, N.W.
1860. ‡*Hogan, Rev. A. R., M.A.*
1865. *Hofmann, Augustus William, LL.D, Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
Hogan, William, M.A., M.R.I.A. Haddington-terrace, Kingstown, near Dublin.
1861. ‡Holcroft, George, C.E. Red Lion-court, St. Ann's-square, Manchester.
1854. *Holcroft, George. Byron's Court, St. Mary's Gate, Manchester.
1856. ‡Holland, Henry. Dumbleton, Evesham.
1858. §Holland, Loton, F.R.G.S. 6 Queen's-villas, Windsor.
*Holland, Philip H. Burial Acts Office, 13 Great George-street, Westminster, S.W.
1865. ‡Holliday, William. New Street, Birmingham.
*Hollingsworth, John. Maidenstone House, Maidenstone Hill, Greenwich, Kent, S.E.

Year of Election.

1866. *Holmes, Charles. London-road, Derby.
1870. §§Holt, William D. 23 Edge-lane, Liverpool.
*Hone, Nathaniel, M.R.I.A. Bank of Ireland, Dublin.
1858. ‡Hook, The Very Rev. W. F., D.D., Dean of Chichester. Chichester.
1847. ‡Hooker, Joseph Dalton, C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S. F.G.S., F.R.G.S. Royal Gardens, Kew.
1865. *Hooper, John P. The Hut, Mitcham Common, Surrey.
1861. §Hooper, William. 7 Pall Mall East, London, S.W.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1869. §Hope, William, V.C. Parsloes, Barking, Essex.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *Hopkinson, John. 12 York-place, Oxford-road, Manchester.
1871. §Hopkinson, John, F.G.S. 8 Lawn-road, Haverstock-hill, London, N.W.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1864. *Horner, Rev. J. J. H. Mells Rectory, Frome.
1858. *Horsfall, Abraham. 17 Park-row, Leeds.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 389 High-street, Cheltenham.
Hotham, Rev. Charles, M.A., F.L.S. Roos, Patrington, Yorkshire.
1868. §§Hotson, W. C. Upper King-street, Norwich.
1859. ‡Hough, Joseph. Wrottesley, near Wolverhampton.
Houghton, The Right Hon. Lord, D.C.L., F.R.S., F.R.G.S. 16 Upper Brook-street, London, W.
Houghton, James. 41 Rodney-street, Liverpool.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1859. ‡Howard, Captain John Henry, R.N. The Deanery, Lichfield.
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. §§Howorth, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, Very Rev. J. S., Dean of Chester. Chester.
1870. §§Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1867. ‡Hudson, William H. H., M.A. 19 Bennett's-hill, Doctors Commons, London, E.C.
1858. *Huggins, William, D.C.L., Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse-hill, Brixton, London, S.W.
1857. §§Huggon, William. 30 Park-row, Leeds.
Hughes, D. Abraham. 9 Grays Inn-square, London, W.C.
Hughes, Frederick Robert.
1871. *Hughes, George Pringle. Middleton Hall, Wooler, Northumberland.
1870. §Hughes, Lewis. 38 St. Domingo-grove, Liverpool.
1868. §Hughes, T. M'K., M.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham.
Hull, Arthur H. 18 Norfolk-road, Brighton.

Year of Election.

1867. §Hull, Edward, M.A., F.R.S., F.G.S. Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hull, William Darley, F.G.S. 36 Queen's Gate-terrace, South Kensington, London, W.
*Hulse, Sir Edward, Bart., D.C.L. 51 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡Hume, Rev. Abraham, D.C.L., LL.D., F.S.A. All Soul's Vicarage, Rupert-lane, Liverpool.
1856. ‡*Humphreys, E. R., LL.D.*
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *Humphry, George Murray, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. The Leys, Cambridge.
1863. *Hunt, Augustus H., M.A., Ph.D. Birtley House, Chester-le-Street, Fence Houses, Co. Durham.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1840. ‡Hunt, Robert, F.R.S., Keeper of the Mining Records. Museum Practical Geology, Jermyn-street, London, S.W.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburg-street, London, W.C.
1859. ‡*Hunter, Dr. Thomas, Deputy Inspector-General of Army Hospitals.*
1855. *Hunter, Thomas O. 24 Forsyth-street, Greenock.
1863. ‡Huntsman, Benjaman. West Retford Hall, Retford.
1869. §Hurst, George. Bedford.
1861. *Hurst, Wm. John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. §§Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. Coney-street, York.
1868. *Hutchison, Robert. Carlowrie, Kirkliston, N.B.
1863. ‡Hutt, The Right Hon. Sir W., K.C.B., M.P. Gibside, Gateshead.
Hutton, Crompton. Putney-park, Surrey, S.W.
Hutton, Daniel. 4 Lower Dominick-street, Dublin.
1864. *Hutton, Darnton. Care of Arthur Lupton, Esq., Headingley, near Leeds.
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
Hutton, Henry. Edenfield, Dundrum, Co. Dublin.
1861. §Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡Huxley, Thomas Henry, Ph.D., LL.D., F.R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 26 Abbey Place, St. John's Wood, London.
1846. ‡Huxtable, Rev. Anthony. Sutton Waldron, near Blandford.
Hyde, Edward. Dukinfield, near Manchester.
1871. *Hyett, Francis A. 13 Hereford-square, Old Brompton, London, S.W.
Hyett, William Henry, F.R.S. Painswick, near Stroud, Gloucestershire.
1847. ‡Hyndman, George C. 5 Howard-street, Belfast.

Ihne, William, Ph.D. Heidelberg.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1871. §Inglis, The Right Hon. John, D.C.L., LL.D., Lord Justice General of Scotland. Edinburgh.
1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. ‡Ingram, J. K., LL.D., M.R.I.A., Regius Professor of Greek. Trinity College, Dublin.

Year of Election.

1854. *Inman, Thomas, M.D. 12 Rodney-street, Liverpool.
1870. *Inman, William. Upton Manor, Liverpool.
1856. ‡*Invararity, J. D. Bombay.*
Ireland, R. S., M.D. 121 Stephen's Green, Dublin.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
Irwin, Rev. Alexander, M.A. Armagh, Ireland.
1862. ‡Iselin, J. F., M.A., F.G.S. 52 Stockwell Park-road, London, S.W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. §§Jack, James. 26 Abercromby-square, Liverpool.
1859. §Jack, John, M.A. Belhelvie by Whitecairns, Aberdeenshire.
1863. *Jackson-Gwilt, Mrs. H. 24 Hereford-square, Gloucester-road, Brompton, London, S.W.
1865. ‡*Jackson, Edwin.*
1858. ‡*Jackson, Edwin W.*
1866. §Jackson, H. W. Springfield, Tooting, Surrey, S.W.
1869. §Jackson, Moses. The Vale, Ramsgate.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
1855. ‡*Jackson, Rev. William, M.A.*
Jacob, Arthur, M.D. 23 Ely-place, Dublin.
1852. ‡Jacobs, Bethel. 40 George-street, Hull.
1867. *Jaffe, David Joseph. (Messrs. Jaffe Brothers) Belfast.
1865. *Jaffray, John. 'Daily Post' Office, New-street, Birmingham.
1859. ‡James, Edward. 9 Gascoyne-terrace, Plymouth.
1860. ‡James, Edward H. 9 Gascoyne-terrace, Plymouth.
James, Colonel Sir Henry, R.E., F.R.S., F.G.S., M.R.I.A. Ordnance Survey Office, Southampton.
1863. *James, Sir Walter. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. 9 Gascoyne-terrace, Plymouth.
1863. ‡Jameson, John Henry. 10 Catherine-terrace, Gateshead.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. §§Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
Jardine, James, C.E., F.R.A.S. Edinburgh.
*Jardine, Sir William, Bart., F.R.S.L. & E., F.L.S. Jardine Hall, Applegarth by Lockerby, Dumfriesshire.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
Jarrett, Rev. Thomas, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. §§Jecks, Charles. Billing-road, Northampton.
1842. **Jee, Alfred S.*
1870. §§Jeffery, F. J. Liverpool.
1856. ‡Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. 193 St. Vincent-street, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. 5 Brick-court, Temple, E.C.; and 25 Devonshire-place, Portland-place, London, W.
1861. *Jeffreys, J. Gwyn, F.R.S., F.L.S., F.G.S., F.R.G.S. 25 Devonshire-place, Portland-place, London, W.
1852. ‡Jellett, Rev. John H., M.A., M.R.I.A., Professor of Natural Philosophy in Trinity College, Dublin. 64 Upper Leeson-street, Dublin.
1842. Jellicorse, John. Chaseley, near Rugeley, Staffordshire.

Year of
Election.

1864. ‡*Jelly, Dr. W. Paston Hall, near Peterborough.*
1862. §Jenkin, H. C. Fleeming, F.R.S., Professor of Civil Engineering in the University of Edinburgh. 5 Fettes-row, Edinburgh.
1864. §Jenkins, Captain Griffith, C.B., F.R.G.S. Derwin, Welshpool.
*Jenkyns, Rev. Henry, D.D. The College, Durham.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. §Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1861. ‡Jennings, Thomas. Cork.
*Jenyns, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1870. §Jerdon, T. C. Care of Mr. H. S. King, 45 Pall Mall, London, S.W.
*Jerram, Rev. S. John, M.A. Chobham Vicarage, Farnborough Station.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *Jevons, W. Stanley, M.A., Professor of Political Economy in Owens College, Manchester. Writhington, Manchester.
1865. *Johnston, G. J. 243 Hagley-road, Birmingham.
1866. §Johnson, John. Knighton Fields, Leicester.
1866. §Johnson, John G. 18A Basinghall-street, London, E.C.
1868. ‡Johnson, J. Godwin. St. Giles's-Street, Norwich.
1868. ‡Johnson, Randall J. Sandown-villa, Harrow.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. §Johnson, Richard C. Warren Side, Blundell Sands, Liverpool.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1864. ‡Johnson, Thomas. 30 Belgrave-street, Commercial-road, London, E.
Johnson, William. The Wynds Point, Colwall, Malvern, Worcestershire.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
Johnston, Alexander Robert, F.R.S. Heatherley, near Wokingham.
1871. §Johnson, A. Keith. 74 Strand, London, W.C.
1859. ‡*Johnston, David, M.D.*
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
Johnston, Edward. Field House, Chester.
1859. ‡Johnston, James. Newmill, Elgin, N. B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.
*Johnstone, James. Aloa House, by Stirling.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. §Jolly, William (H. M. Inspector). Inverness.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1858. ‡Jones, Henry Bence, M.A., M.D., D.C.L., F.R.S., Hon. Sec. to the Royal Institution. 84 Brook-street, London, W.
1854. ‡Jones, Rev. Henry H. Cemetery, Manchester.
1854. ‡Jones, John. 70 Rodney-street, Liverpool.
1864. §Jones, John, F.G.S. Royal Exchange, Middlesborough.
1865. ‡Jones, John. 49 Union-passage, Birmingham.
*Jones, Robert. 2 Castle-street, Liverpool.
1854. *Jones, R. L. 6 Sunnyside, Princes Park, Liverpool.
1847. ‡Jones, Thomas Rymer, Professor of Comparative Anatomy in King's College. 50 Cornwall-road, Westbourne-park, London, W.
1860. ‡Jones, T. Rupert, F.G.S., Professor of Geology and Mineralogy, Royal Military College, Sandhurst. 5 College-terrace, York Town, Surrey.
1864. §Jones, Sir Willoughby, Bart, F.R.G.S. Cranmer Hall, Fakenham, Norfolk.
*Joule, Benjamin St. John B. 28 Leicester-street, Southport, Lancashire.

Year of Election.

1842. *Joule, James Prescott, LL.D., F.R.S., F.C.S. 5 Cliff Point, Higher Broughton, Manchester.
1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, near Wantage, Berkshire.
Joy, Henry Holmes, LL.D., Q.C., M.R.I.A. 17 Mountjoy-square East, Dublin.
1847. ‡Jowett, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John, jun. Leeds.
*Jubb, Abraham. Halifax.
1870. §§Judd, John Wesley, F.G.S. Geological Museum, Jermyn-street, London, S.W.
1863. ‡Jukes, Rev. Andrew. Spring Bank, Hull.

1868. *Kaines, Joseph, F.A.S.L. 8 Osborne-road, Stroud Green-lane, Hornsey.
Kane, Sir Robert, M.D., F.R.S., M.R.I.A., Principal of the Royal College of Cork. 51 Stephen's Green, Dublin.
1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington.
Kay, John Cunliff. Fairfield Hall, near Skipton.
*Kay, John Robinson. Walmersley House, Bury, Lancashire.
Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Great Leighs Rectory, Chelmsford.
1856. ‡Kay-Shuttleworth, Sir James, Bart. Gawthorpe, Burnley.
1855. ‡Kaye, Robert. Mill Brae, Moodies Burn, by Glasgow.
1855. ‡Keddie, William. 15 North-street, Mungo-street, Glasgow.
1866. ‡Keene, Alfred. Eastnoor House, Leamington.
1850. ‡Kelland, Rev. Philip, M.A., F.R.S.L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon Crescent, Edinburgh.
1849. ‡Kelly, John, C.E. 38 Mount Pleasant-square, Dublin.
1857. ‡Kelly, John J. 38 Mount Pleasant-square, Dublin.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1842. Kelsall, J. Rochdale, Lancashire.
1864. *Kemble, Rev. Charles, M.A. Vellore, Bath.
1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.
1858. ‡Kemplay, Christopher. Leeds.
1857. ‡Kennedy, Lieut-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London, W.C.
Kenny, Matthias, M.D. 3 Clifton-terrace, Monkstown, Co. Dublin.
1865. ‡Kenrick, William. Norfolk-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. ‡Kenworth, James Ryley. 7 Pembroke-place, Liverpool.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Auchinraith, by Hamilton, Scotland.
1865. *Kerr, William D., M.D., R.N. Bonnyrigg, Edinburgh.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
1865. *Kinahan, Edward Hudson. 11 Merrion-square North, Dublin.
1860. ‡Kinahan, G. Henry, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1858. ‡Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.
1855. ‡King, Alfred, jun. Everton, Liverpool.

Year of
Election.

1871. *King, Herbert Poole. Avonside, Clifton, Bristol.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.
1864. §King, Kelburne, M.D. 27 George Street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. Avonside, Clifton Down, Bristol.
1842. King, Richard, M.D. 12 Bulstrode-street, London, W.
King, Rev. Samuel, M.A., F.R.A.S. St. Aubins, Jersey.
1870.§§King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, B. Rose Hill, Exeter.
1869. ‡Kingdon, K. Taddiford, Exeter.
1862. ‡Kingsley, Rev. Canon Charles, M.A., F.L.S., F.G.S. Eversley Rectory, Winchfield.
1861. ‡Kingsley, John. 30 St. Ann's-street, Manchester.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1870. §Kinsman, William R. Branch Bank of England, Liverpool.
1867. *Kinnaird, The Hon. Arthur Fitzgerald, M.P. 1 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1863. ‡Kinnaird, The Right Hon. Lord., K.T., F.G.S. Rossie Priory, Inchture, Perthshire.
Kinnear, J. G., F.R.S.E. Glasgow.
1863. ‡Kirkaldy, David. 28 Bartholomew-road North, London, N.W.
1860. ‡Kirkman, Rev. Thomas P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1849. ‡Kirshaw, John William, F.G.S. Warwick.
1868.§§Kirwan, Rev. Richard, M.A. Gittesham Rectory, near Honiton.
1870. §Kitchener, Frank E. Rugby.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. §Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
Knipe, J. A. Botcherby, Carlis e
1842. Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
1870.§§Knowles, Rev. J. L. Grove Villa, Bushey, Herts.
*Knox, George James.
1835. Knox, Thomas B. Union Club, Trafalgar-square, London, W.C.
1870. §§Kynaston, Josiah W. St. Helens, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1862. ‡Lackerstein, Dr. (Care of Messrs. Smith and Elder, 15 Waterloo-place, London, S.W.)
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1850. ‡Laing, David, F.S.A. Scotl. Signet Library, Edinburgh.
1870.§§Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
1846. *Laming, Richard. 10 Gloucester-place, Brighton.
1870. §Lamport, Charles. Upper Norwood, Surrey.
1871. §Lancaster, Edward. Karesforth Hall, Barnesley.
1859. ‡Lang, Rev. John Marshall. Bank House, Morningside, Edinburgh.

Year of Election.

1864. §§Lang, Robert. Hallen Lodge, Henbury, Bristol.
1870. §§Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Manchester.
1840. ‡Lankester, Edwin, M.D., LL.D., F.R.S., F.L.S. 23 Great Marlborough-street, London, W.
1865. §Lankester, E. Ray. Melton House, Hampstead, London, N.W.
*Larcom, Major-General Sir Thomas Aiskew, K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants.
Lassell, William, F.R.S., F.R.A.S. Ray Lodge, Maidenhead.
1861. *Latham, Arthur G. 24 Cross-street, Manchester.
1845. ‡Latham, Robert G., M.A., M.D., F.R.S. 96 Disraeli-road, Putney, S.W.
*La Touche, David Charles, M.R.I.A. Castle-street, Dublin.
1870. §§Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Portsmouth.
1870. *Law, Channell. 5 Champion Park, Camberwell, London, S.E.
1857. ‡Law, Hugh. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. §§Lawrence, Edward. Aigburth, Liverpool.
1869. ‡Lawson, Henry. 8 Nottingham-place, London, W.
1857. ‡Lawson, James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1855. ‡Lawson, John. Mountain Blue Works, Camlachie.
1868. *Lawson, M. Alexander, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 8 Manor House-street, Hull.
Laycock, Thomas, M.D., Professor of the Practice of Physic in the University of Edinburgh. 4 Rutland-street, Edinburgh.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Capt. R. E. Mountjoy, Phœnix Park, Dublin.
Leadbetter, John. Glasgow.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London E.C.; and Harrow.
1870. *Leatham, Baldwin. 7 Westminster Chambers, Westminster, S.W.
1847. *Leatham, Edward Aldam, M.P. Whitley Hall, Huddersfield.
1858. ‡Leather, George. Knostrop, near Leeds.
*Leather, John Towlerton. Leventhorpe Hall, near Leeds.
1858. ‡Leather, John W. Newton Green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1858. ‡Ledgard, William. Potter Newton, near Leeds.
1842. Lee, Daniel. Springfield House, Pendlebury, Manchester.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
Lee, Henry, M.D. Weatheroak, Alve Church, near Bromsgrove.
1853. *Lee, John Edward, F.G.S., F.S.A. The Priory, Caerleon, Monmouthshire.
1859. ‡Lees, William. 5 Meadow Bank, Edinburgh.
*Leese, Joseph. Glenfield, Altrincham, near Manchester.
*Leeson, Henry B., M.A., M.D., F.R.S., F.C.S The Maples, Bonchurch, Isle of Wight.
*Lefroy, J. Henry, Major-General, R.A., F.R.S., F.R.G.S., Director-General of Ordnance. 82 Queen's Gate, London, W.

Year of Election.

*Legh, George Cornwall, M.P. High Legh Hall, Cheshire; and 6 St. James's-place, St. James's-street, London, S.W.
1869.§§Le Grice, A. J. Trereife, Penzance.
1868. ‡Leicester, The Right Hon. The Earl of. Holkham, Norfolk.
1856. ‡Leigh, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. §Leighton, Andrew. 35 High Park-street, Liverpool.
*Leinster, Augustus Frederick, Duke of, M.R.I.A. 6 Carlton House-terrace, London, S.W.; and Carton, Maynooth, Ireland.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870.§§Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1860. ‡Lempriere, Charles, D.C.L. St. John's College, Oxford.
1863. *Lendy, Capt. Auguste Frederic, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex, S.W.
1867. ‡Leng, John. "Advertiser" Office, Dundee.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, John, M.D. Tallaght House, Co. Dublin; and 14 Great Dominick-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §Leonard, Hugh, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1871. §Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡Leslie, T. E. Cliffe, LL.B., Professor of Jurisprudence and Political Economy, Queen's College, Belfast.
1859. ‡Leslie, William. Warthill, Aberdeenshire.
1846. ‡Letheby, Henry, M.B., F.L.S., Medical Officer to the City of London. 41 Finsbury-square, London, E.C.
1866.§§Levi, Dr. Leone, F.S.A., F.S.S., Professor of Commercial Law in King's College, London. 10 Farrar's-building, Temple, London, E.C.
1870.§§Lewis, Alfred Lionel. 151 Church-road, Stoke Newington, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡Liddell, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1855. ‡Liddell, John. 8 Clelland-street, Glasgow.
1859. ‡Ligertwood, George. Blair by Summerhill, Aberdeen.
1864 .§Lightbody, Robert, F.G.S. Ludlow, Salop.
1862. ‡Lilford, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*Limerick, Charles Graves, D.D., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
*Lindsay, Charles. Ridge-park, Lanark.
*Lindsay, Henry L., C.E., M.R.I.A. 1 Little Collins-street West, Montreal, Canada.
1855. *Lindsay, John H. Care of James Jarvie, Esq., 7 Steven-street, Glasgow.
1871. *Lindsay, Rt. Hon. Lord. 47 Brook-street, London, W.
1871. §Lindsay, Rev. T. M. 7 Great Stuart-street, Edinburgh.
1870. §Lindsay, Thomas. 288 Renfrew-street, Glasgow.
1842. *Lingard, John R., F.G.S. Mayfield, Shortlands, by Bromley, Kent.
Lingwood, Robert M., M.A., F.L.S., F.G.S. Cowley House, Exeter.
Lister, James. Liverpool Union Bank, Liverpool.

Year of Election.

1870. §Lister, Thomas. Post Office, Barnsley.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *Liveing, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1860. ‡Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Wellington-road, Edgbaston, Birmingham.
*Lloyd, George, M.D., F.G.S. Birmingham Heath, Birmingham.
1870.§§Lloyd, James. 150 Chatham-street, Liverpool.
1870.§§Lloyd, J. B.
1870. §Lloyd, J. H., M.D. Anglesea.
*Lloyd, Rev. Humphrey, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1865. *Lloyd, Wilson. Moor Hall, Sutton Coldfield, near Birmingham.
1854. *Lobley, James Logan, F.G.S., F.R.G.S. 50 Lansdowne-road, Kensington Park, London, W.
1853. *Locke, John. Care of J. Robertson, Esq., 3 Grafton-street, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1863. ‡Lockyer, J. Norman, F.R.S., F.R.A.S. 24 Fairfax-road, Finchley-road, London, N.W.
Loftus, William Kennett, F.G.S. Calcutta.
*Logan, Sir William Edmond, LL.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of Canada. Montreal, Canada.
1868. ‡Login, Thomas, C.E., F.R.S.E., India.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1871. §Long, John Jex. 12 Whitevale, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, Frederick. Luamdur, near Derby.
1857. ‡Longfield, Rev. George, D.D. 25 Trinity College, Dublin.
Longfield, Mountifort, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1861. *Longman, William, F.G.S. 36 Hyde Park-square, London, W.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
Longridge, William S. Oakhurst, Ambergate, Derbyshire.
1865. *Longsdon, Robert. Church House, Bromley, Kent.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Major Arthur S. H., F.R.A.S. 76 Lancaster Gate, London.
1861. *Lowe, Edward Joseph, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Highfield House Observatory, near Nottingham.
Lowe, George, F.R.S., F.G.S., F.R.A.S. 9 St. John's-wood Park, London, N.W.
1870. §Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1853. *Lubbock, Sir John, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, Kent.

Year of
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1870. §§Lubbock, Montague. High Elms, Farnborough, Kent.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1867. *Luis, John Henry. Cidhmore, Dundee.
1866. *Lund, Charles. Market-street, Bradford.
1850. *Lundie, Cornelius. Tweed Lodge, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton, Jun. The Harehills, Leeds.
1866. §Lycett, Sir Francis. 18 Highbury-grove, London, N.
*Lyell, Sir Charles, Bart., M.A., LL.D., D.C.L., F.R.S., F.L.S., V.P.G.S., Hon. M.R.S.Ed. 73 Harley-street, London, W.
1871. §Lyell, Leonard. 42 Regent's Park-road, London, N.W.
1857. ‡Lyons, Robert D. 31 Upper Merrion-street, Dublin.
1862. *Lyte, Maxwell F., F.C.S. Bagnères de Bigorre, France.
1849. ‡Lyttelton, The Right Hon. Lord, D.C.L., F.R.S. 12 Stratton-street, London, W.

1852. ‡MacAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1868. ‡M'Allan, W. A. Norwich.
*M'Andrew, Robert, F.R.S. Isleworth House, Isleworth, Middlesex.
1866. *M'Arthur, A. Raleigh Hall, Brixton Rise, London, S.W.
1840. Macaulay, James, M.D. 22 Cambridge-road, Kilburne, London, N.W.
1871. §M'Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.
*MacBrayne, Robert. Househill Hamlet, Glasgow.
1866. ‡M'Callan, Rev. J. F., M.A. Basford, near Nottingham.
1855. ‡M'Callum, Archibald K., M.A. House of Refuge, Duke-street, Glasgow.
1863. †M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, James, F.G.S. Holmfrith, Yorkshire.
1857. ‡M'Causland, Dominick. 12 Fitzgibbon-street, Dublin.
1865. *M'Clean, John Robinson, F.R.S., F.G.S. 2 Park-street, Westminster, S.W.
1840. M'Clelland, James. 32 Pembridge Square, London, W.
1868. ‡M'Clintock, Captain Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
*M'Connel, James. The Furze, Esher, Surrey.
1859. **M'Connell, David C., F.G.S.*
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1851. ‡M'Coy, Frederick, F.G.S., Professor of Zoology and Natural History in the University of Melbourne, Australia.
*M'Culloch, George, M.D. Cincinnati, United States.
Macdonald, William, M.D., F.R.S.E., F.L.S., F.G.S., Professor of Civil and Natural History. St. Andrews, N. B.
1871. §M'Donald, William. Yopohama, Japan. Care of R. K. Knenitt, Esq., Sun-court, Cornhill, E.C.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
*M'Ewan, John. 20 Royal Crescent, Glasgow.
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1871. §M'Farlane, Donald. The College Laboratory, Glasgow.
1855. ‡M'Farlane, Walter. Saracen Foundry, Glasgow.

Year of Election.

1854. *Macfie, Robert Andrew, M.P. Ashfield Hall, Neston, near Chester.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1852. *M'Gee, William, M.D. 10 College-square North, Belfast.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. Wallace-grove, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *M'Intosh, W. C., M.D., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. Water-street, Liverpool.
1871. §Mackay, Rev. Dr. A., F.R.G.S. Oakland Villa, Hatton-place, Edinburgh.
1865. ‡Mackeson, H. B. Hyde, Kent.
1865. ‡ Mackintosh, Daniel, F.G.S. Chichester.
1855. ‡M'Kenzie, Alexander. 89 Buchanan-street, Glasgow.
*Mackenzie, James. Glentore, by Glasgow.
1865. ‡*Mackenzie, Kenneth Robert Henderson, F.S.A., F.A.S.L.*
1859. ‡Mackie, David. Mitchell-place, Aberdeen.
1867. §Mackie, Samuel Joseph, F.G.S. 84 Kensigton Park-road, London, W.
*Mackinlay, David. Great Western-terrace, Glasgow.
1867. §Mackson, H. G. 25 Cliff Road, Woodhouse, Leeds.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §MacLaren, Duncan, M.P. Newington House, Edinburgh.
1859. ‡Maclear, Sir Thomas, F.R.S., F.R.G.S., F.R.A.S., late Astronomer Royal at the Cape of Good Hope.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Camden-hill-road, London, W.
1868. §M'Leod, Herbert. Royal College of Chemistry, Oxford-street, London, W.
1861. *Maclure, John William. 2 Bond-street, Manchester.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey.
1871. §M'Nab, William Ramsay, M.D. Royal Agricultural College, Cirencester.
1870. §Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.
MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MacNeill, Sir John, LL.D., F.R.S., M.R.I.A., Professor of Civil Engineering in Trinity College, Dublin. Mount Pleasant, Dundalk.
1850. ‡Macnight, Alexander. 12 London-street, Edinburgh.
1859. ‡Macpherson, Rev. W. Kilmuir Easter, Scotland.
Macredie, P. B. Mure, F.R.S.E. Irvine, Ayrshire.
1852. *Macrory, Adam John. Duncairn, Belfast.
*Macrory, Edmund, M.A. 40 Leinster-square, Bayswater, London, W.
1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡Macvicar, Rev. John Gibson, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
Magor, J. B. Redruth, Cornwall.
1869. §Main, Rev. R., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1869. ‡Main, Robert. Admiralty, Somerset House, W.C.
1866. §Major, Richard H., F.S.A., F.R.G.S. British Museum, London, W.C.

Year of Election.

*Malahide, Talbot de, The Right Hon. Lord, M.A., F.R.S., F.G.S., F.S.A. Malahide Castle, Co. Dublin.
*Malcolm, Frederick. Mordon College, Blackheath, London, S.E.
1870. *Malcolm, Sir James, Bart. The Priory, St. Michael's Hamlet, Aigburth, Liverpool.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
*Mallet, Robert, Ph.D., F.R.S., F.G.S., M.R.I.A. The Grove, Clapham-road, Clapham, London, S.W.
1857. ‡Mallet, Dr. John William. University of Alabama, U. S.
1846. ‡Manby, Charles, F.R.S., F.G.S. 24 Great George-street, London, S.W.
1863. ‡*Mancini, Count de, Italian Consul.*
1866. §Mann, Robert James, M.D., F.R.A.S. 6 Duke-street, Adelphi, London, W.C.; and 4 Belmont-villas, Surbiton Hill.
Manning, The Right Rev. H.
1866. ‡Manning, John. Waverley-street, Nottingham.
1870. §§Manifold, W. H. 45 Rodney-street, Liverpool.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1865. ‡March, J. F. Fairfield House, Warrington.
1870. §§Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡Markham, Clements R., C.B., F.L.S., F.R.G.S. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.
1871. §Marreco, A. F. Laboratory, College of Medicine, Newcastle-on-Tyne.
Marriott, John. Allerton, Liverpool.
1857. §Marriott, William, F.C.S. Grafton-place, Huddersfield.
1858. ‡Marriott, William Thomas. Wakefield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1866. ‡Marsh, Dr. J. C. L. Park-row, Nottingham.
1870. §Marsh, John. Rann Lea, Rainhill, Liverpool.
1856. ‡Marsh, M. H. Wilbury Park, Wilts.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
Marshall, James. Headingly, near Leeds.
1852. ‡Marshall, James D. Holywood, Belfast.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
*Marshall, James Garth, M.A., F.G.S. Headlingley House, Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §Marten, Edward Bindon. 13 High-street, Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial Circus, Cheltenham.
1871. §Martin, Rev. Hugh, M.A. Greenhill-cottage, Lasswade by Edinburgh.
1870. §§Martin, Robert, M.D. 120 Upper Brook-street, Manchester.
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. *Martin, William, Jun. Leafield-place, Dundee.
*Martindale, Nicholas. 12 Cornwall-terrace, Regent's Park, London, N.W.
*Martineau, Rev. James. 10 Gordon-street, Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1847. ‡Maskelyne, Nevil Story, M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. British Museum, London, W.C.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. §§Massey, Thomas. 5 Gray's-Inn-square, London, W.C.
1870. §§Massy, Frederick. 50 Grove-street, Liverpool.

Year of Election.

1868. §§Mason, James Wood, F.G.S. 1 Glebe-place, Stoke Newington, London, N.
1865. *Mathews, G. S. 15 Waterloo-street, Birmingham.
1861. *Mathews, William, jun., M.A., F.G.S. 51 Carpenter-road, Edgbaston, Birmingham.
1859. ‡Matthew, Alexander C. 3 Canal-terrace, Aberdeen.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
*Matthews, Henry, F.C.S. 60 Gower-street, London, W.C.
1860. §Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1855. ‡Maule, Rev. Thomas, M.A. Partick, near Glasgow.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1864. *Maxwell, Francis. Speddock, near Dumfries.
*Maxwell, James Clerk, M.A., LL.D., F.R.S., L. & E. Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1865. *May, Walter. Elmley Lodge, Harborne, Birmingham.
1868. §Mayall, J. E., F.C.S. Hove-place House, Brighton.
*Mayne, Rev. Charles, M.R.I.A. Killaloe, Co. Clare, Ireland.
1863. §Mease, George D. Bylton Villa, South Shields.
1863. ‡Mease, Solomon. Cleveland House, North Shields.
‡Meath, Samuel Butcher, D.D., Lord Bishop of. Ardbraccan, Co. Meath.
1861. ‡Medcalf, William.
1871. §Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1867. ‡Meldrum, Charles. Mauritius.
1866. ‡Mello, Rev. J. M. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1862. §Mennell, Henry J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §Merrifield, Charles W., F.R.S., Principal of the Royal School of Naval Architecture, Superintendent of the Naval Museum at South Kensington, Hon. Sec. I.N.A. 23 Scarsdale-villas, Kensington, London, S.W.
1871. §Mersen, John. Northumberland County Asylum, Morpeth.
1863. §§Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. §Miall, Louis C. Bradford, Yorkshire.
1847. *Michell, Rev. Richard, D.D., Principal of Magdalen Hall, Oxford.
1865. ‡Michie, Alexander. 26 Austin Friars, London, E.C.
1865. §Middlemore, William. Edgbaston, Birmingham.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
1855. ‡Miles, Rev. Charles P., M.D. 58 Brompton-crescent, London, S.W.
1859. ‡Millar, John. Lisburn, Ireland.
1863. §Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road London, N.E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1859. ‡Miller, James, jun. Greenock.
1865. ‡Miller, Rev. J. C., D.D. The Vicarage, Greenwich, London, S.E.
*Miller, Patrick, M.D. The Grove, Mount Radford, Exeter.

Year of Election.

1861. *Miller, Robert. Broomfield House, Reddish, near Manchester.
Miller, William Hallows, M.A., LL.D., For. Sec. R.S., F.G.S., Professor of Mineralogy in the University of Cambridge. 7 Scroope-terrace, Cambridge.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S.. 15 Northumberland-street, Strand, London, W.C.
1842. Milligan, Robert. Acacia in Randon, Leeds.
1868. §Mills, Edmund J. 12 Pemberton-terrace, St. John's Wood, London, N.
*Mills, John Robert. Bootham, York.
1867. ‡Milne, James. Murie House, Errol, by Dundee.
Milne, Admiral Sir Alexander, G.C.B., F.R.S.E. 65 Rutland Gate, London, S.W.
*Milne-Home, David, M.A., F.R.S.E., F.G.S. Paxton House, Berwick, N.B.
1854. *Milner, William. Phœnix Safe Works, Liverpool.
1864. *Milton, The Right Hon. Lord, M.P., F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 128 West-street, Tradeston, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1863. ‡Mitchell, C. Walker, Newcastle-on-Tyne.
1870. §Mitchell, John. York House, Clitheroe.
1868. §Mitchell, John, jun. Pole Park House, Dundee.
1862. *Mitchell, William Stephen, LL.B., F.L.S., F.G.S. Caius College, Cambridge.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §Moffat, Thomas, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866. §Moggridge, Matthew, F.G.S. Ditton Lodge, Thames Ditton, Surrey.
1855. §Moir, James. 174 Gallogate, Glasgow.
1861. ‡Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §Molyneux, William, F.G.S. Manor House, Burton-upon-Trent.
1853. ‡Monday, William, Hon. Sec. Hull Lit. and Phil. Soc. 6 Jarratt-street, Hull.
1860.§§Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham, Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1857. §Moore, Arthur. Cradley House, Clifton, Bristol.
1859. §Moore, Charles, F.G.S. 6 Cambridge-terrace, Bath.
1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*Moore, John Carrick, M.A., F.R.S., F.G.S. 113 Eaton-street, London, S.W.; and Corswall, Wigtonshire.
1866. *Moore, Thomas, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡Moore, Thomas John, Cor.M.Z.S. Free Public Museum, Liverpool.
1835. Moore, William D., M.D. 40 Fitzwilliam-square West, Dublin.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1871. §More, Alexander, F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1861. ‡Morewood, Edmund. Cheam, Surrey.
Morgan, Captain Evan, R.A.
1868. ‡Morgan, Thomas H. Oakhurst, Hastings.
1849. ‡Morgan, William. 37 Waterloo-street, Birmingham.

Year of Election.

Morley, George. Park-place, Leeds.
1863. ‡Morley, Samuel, M.P. Lenton-grove, Nottingham.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
1861. *Morris, David. Royal Exchange, Manchester.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1861. ‡Morris, William. The Grange, Salford.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1867. §Morrison, William R. Dundee.
1863. ‡Morrow, R. J. Bentick Villas, Newcastle-on-Tyne.
1865. §Mortimer, J. R. St. John's Villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §Morton, George H., F.G.S. 21 West Derby-street, Liverpool.
1858. *Morton, Henry Joseph. Garforth House, West Garforth, near Leeds.
1871. §Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1847. ‡Moseley, Rev. Henry, M.A., F.R.S. Olveston Vicarage, near Bristol.
1868. ‡Moseley, H. N. Olveston, Bristol.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
1862. ‡*Mosheimer, Joseph.*
Mosley, Sir Oswald, Bart., D.C.L., F.L.S., F.G.S. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1870. §§Moss, John Miles. Springbank, Waterloo, Liverpool.
1853. *Moss, William Henry. Kingston-terrace, Hull.
1864. §Mosse, J. R. (H. S. King & Co., 65 Cornhill, London, E.C.) General Manager's Office, Mauritius Railway, Port Louis, Mauritius.
1869. §Mott, J. Albert. Sandfield, Waterloo, Liverpool.
1865. §§Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. 1 De Montfort-street, Leicester.
1862. *Mouat, Frederick John, M.D., late Inspector-General of Prisons, Bengal. 12 Durham Villas, Campden-hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. 21 Camden-crescent, Bath.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. 7 Market-street, Manchester.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1871. §Muir, W. Hamilton. Toravon, Stirlingshire.
1871. *Muirhead, Henry, M.D. Bushey-hill, Cambuslang, Lanarkshire.
Muirhead, James. 90 Buchanan-street, Glasgow.
1857. ‡Mullins, M. Bernard, M.A., C.E. 1 Fitzwilliam-square South, Dublin.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡Mundella, A. J., M.P., F.R.G.S. The Park, Nottingham.
1864. *Munro, Major-General William, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1864. §Murch, Jerom. Cranwells, Bath.
*Murchison, John Henry, F.G.S. Surbiton-hill, Kingston.
1864. *Murchison, K. R. 10 Victoria-park, Dover.
1864. ‡Murchison, Captain R. M. Caerbaden House, Cleveland-walk, Bath.
1855. ‡Murdock, James B. Hamilton-place, Langside, Glasgow.
1858. ‡Murgatroyd, William. Bank Field, Bingley.
Murley, Rev. C. H. South Petherton, Ilminster.

Year of Election.

1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. §Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1850. ‡Murray, Andrew, F.L.S. 67 Bedford Gardens, Kensington, London, W.
1871. §Murray, Captain, R.N. Murrathwaite, Ecclefachan, Scotland.
1871. §Murray, Dr. Ivor. Hong-Kong, China.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. §Murray, John. 2 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. 11 Great Queen-street, Westminster, S.W.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
*Murton, James. Silverdale, near Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven. Halifax.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1865. ‡Myers, Rev. E., F.G.S. 3 Yewtree-road, Birmingham.
1859. §Mylne, Robert William, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1850. ‡Nachot, H. W., Ph.D. 73 Queen-street, Edinburgh.
1842. Nadin, Joseph. Manchester.
1855. *Napier, James R., F.R.S. 22 Blythwood-square, Glasgow.
1839. *Napier, Right Hon. Sir Joseph, Bart. 4 Merrion-square, Dublin.
*Napier, Captain Johnstone. Tavistock House, Salisbury.
1855. ‡Napier, Robert. West Chandon, Gareloch, Glasgow.
Napper, James William L. Loughcrew, Oldcastle., Co. Meath.
1866. ‡Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.
1850. *Nasmyth, James. Penshurst, Tunbridge.
1864. ‡Natal, William Colenso, Lord Bishop of.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1867. §Neaves, The Right Hon. Lord. 7 Charlotte-square, Edinburgh.
1853. ‡Neill, William, Governor of Hull Jail. Hull.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡Neilson, W. Montgomerie. Glasgow.
Ness, John. Helmsley, near York.
1868. ‡Nevill, Rev. H. R. Great Yarmouth.
1866. *Nevill, Rev. Samuel Tarratt, B.A., F.L.S. Shelton Rectory, near Stoke-upon-Trent.
1861. ‡Nevill, Thomas Henry. 17 George-street, Manchester.
1857. ‡Neville, John, C.E., M.R.I.A. Dundalk, Ireland.
1852. ‡Neville, Parke, C.E. Town Hall, Dublin.
1869. §Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare-hill, Littleborough, Lancashire.
*Newall, Robert Stirling. Ferndene, Gateshead-upon-Tyne.
1867.§§Newbegin, James. Norwich.
1866. *Newdegate, Albert L. 14 Dover-street, Piccadilly, London, W.
1842. *Newman, Professor Francis William. 1 Dover-place, Clifton, Bristol.
*Newman, William. Darley Hall, near Barnsley, Yorkshire.
1863. *Newmarch, William, F.R.S. Heath View, West-side, Clapham Common, London, S.W.
1866. *Newmarch, William Thomas. 4 Huntington-place, Tynemouth.

Year of Election.

1858. ‡*Newsome, Thomas. Park-road, Leeds.*
1860. *Newton, Alfred, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.
1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Dean of Guild. Dundee.
Nicholl, Iltyd, F.L.S. Uske, Monmouthshire.
1848. ‡Nicholl, W. H. The Ham, Cowbridge, Glamorganshire.
1866. §Nicholson, Sir Charles, Bart., D.C.L., LL.D., M.D., F.G.S., F.R.G.S. 26 Devonshire Place, Portland-place, London, W.
*Nicholson, Cornelius, F.G.S. Welfield, Muswell-hill, London, N.
1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
1871. §Nicholson, E. Chambers. Herne-hill, London, S.E.
1867. ‡Nicholson, Henry Alleyne, D.Sc., F.G.S. Newhaven Park, Newhaven, near Edinburgh.
*Nicholson, John A., A.M., M.B., Lic. Med., M.R.I.A. Balrath Burry, Kells, Co. Meath.
1850. ‡Nicol, James, F.R.S.E., F.G.S., Professor of Natural History in Marischal College, Aberdeen.
1867. ‡Nimmo, Dr. Matthew, L.R.C.S.E. Nethergate, Dundee.
Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
1864. ‡Noad, Henry M., Ph.D., F.R.S., F.C.S. 72 Hereford-road, Bayswater, London, W.
1863. *Noble, Captain William R. Elswick Works, Newcastle-on-Tyne.
1870. §§Nolan, Joseph. 14 Hume-street, Dublin.
1860. *Nolloth, Matthew S., Captain R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §Norman, Rev. Alfred Merle, M.A. Houghton-le-Spring, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
Norris, Charles. St. John's House, Halifax.
1865. ‡Norris, Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1866. ‡North, Thomas. Cinder Hill, Nottingham.
Northampton, Charles Douglas, The Right Hon. Marquis of. 145 Piccadilly, London, W.; and Castle Ashby, Northamptonshire.
1869. §§Northcote, Right Hon. Sir Stafford H., Bart., C.B., M.P. Pynes, Exeter; and 42 Harley-street, London, W.
*Northwick, The Right Hon. Lord, M.A. 22 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1869. §Noyes, H. C. Victoria-terrace, Heavitree, Exeter.
1859. ‡Nuttall, James. Wellfield House, Todmorden.

O'Beirne, James, M.D. 11 Lower Gardiner-street, Dublin.
O'Brien, Baron Lucius. Dromoland, Newmarket-on-Fergus, Ireland.
O'Callaghan, George. Tallas, Co. Clare.
1858. *O'Callaghan, Patrick, LL.D., D.C.L. 16 Clarendon-square, Leamington.
Odgers, Rev. William James. Sion-hill, Bath.

Year of
Election.

1858. *Odling, William, M.B., F.R.S., F.C.S., Fullerian Professor of Chemistry in the Royal Institution, London. Sydenham-road, Croydon, Surrey.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. §§O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1866. ‡Ogden, James. Woodhouse, Loughborough.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*Ogilvie, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. 29 Union-place, Aberdeen.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
1863. ‡Ogilvy, Sir John, Bart., M.P. Inverquharity, N. B.
1863. ‡*Ogle, Rev. E. C.*
*Ogle, William, M.D., M.A. 98 Friar Gate, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John. 20 Kildare-street, Dublin.
1862. ‡O'Kelly, Joseph, M.A. 51 Stephen's Green, Dublin.
1857. ‡O'Kelly, Matthias J. Dalkey, Ireland.
1853. §Oldham, James, C.E. Austrian Chambers, Hull.
1857. *Oldham, Thomas, M.A., LL.D., F.R.S., F.G.S., M.R.I.A., Director of the Geological Survey of India. 1 Hastings-street, Calcutta.
1860. ‡O'Leary, Professor Purcell, M.A. Sydney-place, Cork.
1863. ‡Oliver, Daniel. Royal Gardens, Kew.
*Ommanney, Erasmus, Rear-Admiral, C.B., F.R.S., F.R.A.S., F.R.G.S 6 Talbot-square, Hyde-park, London, W.; and United Service Club, Pall Mall, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1842. Ormerod, George Wareing, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham-hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
Orpen, John H., LL.D., M.R.I.A. 58 Stephen's Green, Dublin.
1854. ‡Orr, Sir Andrew. Blythwood-square, Glasgow.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. South Bank, Edgbaston, Birmingham.
1854. §Outram, Thomas. Greetland, near Halifax.
Overstone, Samuel Jones Lloyd, Lord, F.G.S. 22 Norfolk-street, Park-lane, London, W.; and Wickham Park, Bromley.
1870. §§Owen, Harold. Tue Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
Owen, Richard, M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1863. *Ower, Charles, C.E. 11 Craigie-terrace, Dundee.

1859. ‡Page, David, LL.D., F.R.S.E., F.G.S. 44 Gilmore-place, Edinburgh.
1863. ‡Paget, Charles. Ruddington Grange, near Nottingham.
1870. §§Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea, Hull.
1857. *Parker, Alexander, M.R.I.A. William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.

Year of Election.

Parker, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard. Dunscombe, Cork.
Parker, Rev. William. Saham, Norfolk.
1865. *Parker, Walter Mantel. Warren-corner House, near Farnham, Surrey.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. 5 St. Mary's-row, Birmingham.
1864. §§Parkes, William. 14 Park-street, Westminster, S.W.
1859. ‡Parkinson, Robert, Ph.D. Bradford, Yorkshire.
1863. ‡Parland, Captain. Stokes Hall, Jesmond, Newcastle-on-Tyne.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, N.E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N. B.
Partridge, Richard, F.R.S., Professor of Anatomy to the Royal Academy of Arts, and to King's College, London. 17 New-street, Spring-gardens, London, S.W.
1865. *Parsons, Charles Thomas. 8 Portland-road, Edgbaston, Birmingham.
1855. ‡Paterson, William. 100 Brunswick-street, Glasgow.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. H. Ardmara House, Bangor, Co. Down.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1871. §Patterson, John. Manchester.
1839. *Patterson, Robert, F.R.S. 59 High-street, Belfast.
1863. ‡Pattinson, John. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-on-Tyne.
1867. ‡Pattison, Samuel R., F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1863. §Paul, Benjamin H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡Pavy, Frederick William, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1851. ‡Payne, Joseph. 4 Kildare Gardens, Bayswater, London, W.
1866. §§Payne, Dr. Joseph F. 4 Kildare-gardens, Bayswater, London, W.
1847. §Peach, Charles W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.
1868. ‡Peacock, Ebenezer. 32 University-street, London, W.C.
1863. §Peacock, Richard Atkinson. St. Heliers, Jersey.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, E.C.
Pearson, Charles. 10 Torrington-square, London, W.C.
1870. §§Pearson, Rev. Samuel. 3 Greenheys-road, Prince's-park, Liverpool.
1863. §Pease, H. F. Brinkburn, Darlington.
1852. ‡Pease, Joseph Robinson. Hesslewood.
1863. *Pease, Joseph W., M.P. Hutton Hall, Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.R.G.S. Wisbeach, Cambridgeshire.
*Peckover, Algernon, F.L.S. Harecroft House, Wisbeach, Cambridgeshire.
*Peckover, William, F.S.A. Wisbeach, Cambridgeshire.
*Peel, George. Soho Iron Works, Manchester.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John. Mount-street, Manchester.
1868. §§Pendergast, Thomas. Lancefield, Cheltenham.

Year of
Election.

1856. §Pengelly, William, F.R.S., F.G.S. Lamorna, Torquay.
1845. ‡Percy, John, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Government School of Mines. Museum of Practical Geology, Jermyn-street, S.W.; and 1 Gloucester-crescent, Hyde-park, London.
*Perigal, Frederick. Chatcots, Belsize Park, London, N.W.
1868. *Perkin, William Henry, F.R.S., F.C.S. Seymour Villa, Sudbury, N.W.
1861. ‡Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1867. ‡Perkins, William. 6 Russell-place, Fitzroy-square, London, W.
1861. ‡Perring, John Shae. 104 King-street, Manchester.
Perry, The Right Rev. Charles, M.A., Bishop of Melbourne, Australia.
*Perry, Rev. S. G. F., M.A. Tottington Parsonage, near Bury.
1870. *Perry, Rev. S. J. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, Rochdale.
Pett, Samuel, F.G.S. 7 Albert-road, Regent's Park, London, N.W.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1871. * Peyton, John E. H., F.R.A.S. 108 Marina, St. Leonards-on-Sea.
1867. ‡Phayre, Colonel Sir Arthur. East India United Service Club, St. James's Square, London, S.W.
1863. *Phené, John Samuel, F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, Chelsea, London, S.W.
1870. §Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
*Philips, Mark. Snitterfield, Stratford-on-Avon.
Philips, Rob. N. The Park, Manchester.
1863. ‡Philipson, Dr. 1 Saville Row, Newcastle-on-Tyne.
1856. *Phillipps, Sir Thomas, Bart., M.A., F.R.S., F.G.S. Thirlestaine House, Cheltenham.
1859. *Phillips, Major-General Sir Frowell. 1 Vere-street, Cavendish-square, London, W.
1862. ‡Phillips, Rev. George, D.D., Queen's College, Cambridge.
1870. §Phillips, J. Arthur. Cressington-park, Aigburth, Liverpool.
*Phillips, John, M.A., LL.D., D.C.L., F.R.S., F.G.S., Professor of Geology in the University of Oxford. Museum House, Oxford.
1859. ‡*Phillips, Major J. Scott.*
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡Phipson, T. L., Ph.D. 4 The Cedars, Putney, Surrey.
1864. ‡Pickering, William. Oak View, Clevedon.
1861. ‡Pickstone, William. Radcliff Bridge, near Manchester.
1870. §Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. §Pigot, Rev. E. V. Malpas, Cheshire.
1871. §Pigot, Thomas F. Royal College of Science, Dublin.
1865. ‡Pike, L. Owen. 25 Carlton-villas, Maida Vale, London, W.
*Pike, Ebenezer. Besborough, Cork.
1864. ‡*Pilditch, Thomas.*
1857. ‡Pilkington, Henry M., M.A., Q.C. 35 Gardiner's-place, Dublin.
1863. *Pim, Captain Bedford C. T., R.N., F.R.G.S. 11 Belsize-square, Hampstead, London, N.W.
Pim, George, M.R.I.A. Brennan's Town, Cabinteely, Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
Pim, William H. Monkstown, Dublin.
1861. ‡Pincoffs, Simon. Crumpsall Lodge, Cheetham-hill, Manchester.

Year of Election.

1868. ‡Pinder, T. R. St. Andrews, Norwich.
1859. ‡Pirrie, William, M.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1869. §Plant, James. 40 West-terrace, Leicester.
1865. ‡Plant, Thomas L. Camp-hill, and 33 Union-street, Birmingham.
1863. *Platt, John, M.P. Werneth Park, Oldham, Lancashire.
1867. ‡Playfair, Lieut.-Colonel, H.M. Consul, Algeria.
1842. Playfair, Lyon, C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 4 Queensberry Place, South Kensington, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *Pochin, Henry Davis, M.P., F.C.S. Broughton Old Hall, Manchester,
1846. ‡Pole, William, Mus. Doc., F.R.S. The Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A., Rector of St. Runwald's. 6 St. Mary's-terrace, Colchester.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Pooley, Thomas A., B.Sc. South Side, Clapham-common, London, S.W.
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
*Porter, Henry J. Ker, M.R.I.A. 91 Dean-street, Soho, London, W.
1866. §Porter, Robert. Beeston, Nottingham.
Porter, Rev. T. H., D.D. Desertcreat, Co. Armagh.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*Potter, Edmund, M.P., F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
1863. ‡Potts, James. 52½ Quayside, Newcastle-on-Tyne.
1857. *Pounden, Captain Londsdale, F.R.G.S. Junior United Service Club, St. James's-sq., London, S.W.; and Brownswood, Co. Wexford.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1864. ‡Prangley, Arthur. 2 Burlington-buildings, Redland, Bristol.
Pratt, The Venerable John H., M.A., F.R.S., Archdeacon of Calcutta. Calcutta.
1869. *Preece, William Henry. Grosvenor House, Southampton.
1864. *Prentice, Manning. Violet Hill, Stowmarket, Suffolk.
Prest, The Venerable Archdeacon Edward. The College, Durham.
Prest, John. Blossom-street, York.
*Prestwich, Joseph, F.R.S., Pres. G.S. 69 Mark-lane, London, E.C.; and Shoreham, near Sevenoaks.
1871. §Price, Astley Paston. 47 Lincoln's Inn Fields, London, W.C.
1856. *Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. 11 St. Giles's-street, Oxford.
1870. §Price, Captain E. W., M.P. Tibberton Court, Gloucester.
Price, J. T. Neath Abbey, Glamorganshire.
1865. ‡Prideaux, J. Symes. 209 Piccadilly, London, W.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1865. *Prichard, Thomas, M.D. Abington Abbey, Northampton.
1835. *Pritchard, Andrew. 87 St. Paul's-road, Canonbury, London, N.
1846. *Pritchard, Rev. Charles, M.A., F.R.S., F.R.A.S., F.G.S., Professor of Astronomy in the University of Oxford.
1871. §Procter, James. Morton House, Clifton, Bristol.

Year of Election.

1863. ‡Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. 108 Pembroke-road, Clifton, Bristol.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Co. Durham.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. §§Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1871. *Puckle, Thomas John. Care of J. P. Gassiot, Esq., Clapham Common, S.W.
1864. ‡Pugh, John. Aberdovey, Shrewsbury.
1867. ‡Pullar, John. 4 Leonard Bank, Perth.
1867. §Pullar, Robert. 6 Leonard Bank, Perth.
1842. *Pumphrey, Charles. 33 Frederick-street, Edgbaston, Birmingham.
Punnett, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1869. ‡Purchas, Rev. W. H. St. James's, Gloucester.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡Purdy, Frederick, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1866. ‡Purser, Professor John. Queen's College, Belfast.
1860. *Pusey, S. E. Bouverie. 7 Green-street, London, W.; and Pusey, Farringdon.
1861. *Pyne, Joseph John. Hope House, Heald Grove, Rusholme, Manchester.
1868. §Pye-Smith, P. H., M.D. Finsbury-square, E.C., and Guy's Hospital, London, S.E.

1870. §§Rabbits, W. T. Forest-hill, London, S.E.
1860. ‡Radcliffe, Charles Bland, M.D. 4 Henrietta-street, Cavendish-square, London, W.
1870. §§Radcliffe, D. R. Phœnix Safe-works, Windsor, Liverpool.
*Radford, William, M.D. Sidmount, Sidmouth.
1861. ‡Rafferty, Thomas. 13 Monmouth-terrace, Rusholme, Manchester.
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. §§Raffles, William Winter. Sunnyside, Prince's-park, Liverpool.
1859. ‡Rainey, George, M.D. 17 Golden-square, Aberdeen.
1855. ‡Rainey, Harry, M.D. 10 Moore-place, Glasgow.
1864. ‡Rainey, James T. 8 Widcomb-crescent, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. §§Ramsay, Alexander, jun., F.G.S. 45 Norland-square, Notting Hill, London, W.
1845. ‡Ramsay, Andrew Crombie, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Great Britain, Professor of Geology in the Royal School of Mines. Museum of Practical Geology, Jermyn-street, London, S.W.
1863. ‡Ramsay, D. R. Wallsend, Newcastle-on-Tyne.
1867. ‡Ramsay, James, Jun. Dundee.
1861. ‡Ramsay, John. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 15 Somerset-street, Portman-square, London, W.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker. Cambridge.
Rand, John. Wheatley-hill, Bradford, Yorkshire.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1855. ‡Randolph, Charles. Pollockshiels, Glasgow.
1860. *Randolph, Rev. Herbert, M.A. Marcham, near Abingdon.
Ranelagh, the Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.

Year of Election.

1850. §Rankine, William John Macquorn, LL.D., F.R.S. L. & E., Regius Professor of Civil Engineering and Mechanics in the University of Glasgow. 59 St. Vincent-street, Glasgow.
1861.§§Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1863. §Ransom, William Henry, M.D., F.R.S. Low Pavement, Nottingham.
1868. *Ranson, Edwin. Kempstone, near Bedford.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1868. ‡Rassam, Hormuzed.
*Ratcliff, Colonel Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. §Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870.§§Rathbone, Benson. Exchange-buildings, Liverpool.
1870.§§Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. 11 Rumford-street, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
Rawdon, William Frederick M.D. Bootham, York.
1870.§§Rawlins, G. W. The Hollies, Rainhill, Liverpool.
*Rawlins, John. Llewesog Hall, near Denbigh.
1866. *Rawlinson, George, M.A., Camden Professor of Ancient History in the University of Oxford. 53 Broad-street, Oxford.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1865.§§Rayner, Henry. Liverpool-road, Chester.
1870.§§Rayner, Joseph (Town Clerk). Liverpool.
1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.
1865. ‡Read, William. Albion House, Epworth, Bawtry.
*Read, W. H. Rudstone, M.A., F.L.S. Blake-street, York.
1870. §Reade, Thomas M. Blundell Sands, Liverpool.
1862. *Readwin, Thomas Allison, F.G.S. 29 Moss-lane West, Manchester.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. *Reé, H. P. 27 Faulkner-street, Manchester.
1861. ‡Reed, Edward J., Vice-President of the Institute of Naval Architects. Chorlton-street, Manchester.
1869. ‡Reid, J. Wyatt. 40 Great Western-terrace, Bayswater, London, W.
1850. ‡Reid, William, M.D. Cuivie, Cupar, Fife.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
Rennie, Sir John, Knt., F.R.S., F.G.S., F.S.A., F.R.G.S. 7 Lowndes-square, London, S.W.
1860. ‡Rennison, Rev. Thomas, M.A. Queen's College, Oxford.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1869. ‡Révy, J. J. 16 Great George-street, Westminster, S.W.
1870. *Reynolds, Osborne, Professor of Engineering in Owens College, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
1871. §Reynolds, S. R. Royal Dublin Society, Kildare-street, Dublin.
Reynolds, William, M.D. Coeddu, near Mold, Flintshire.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1868. §Richards, Rear-Admiral George H., F.R.S., F.R.G.S., Hydrographer to the Admiralty. The Admiralty, Whitehall, London, S.W.
1863. §Richardson, Benjamin Ward, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.

Year of Election.

1861.§§Richardson, Charles. Almondbury, Bristol.
1869. *Richardson, Charles. West End, Abingdon, Berks.
1863. *Richardson, Edward, jun. 3 Lovaine-place, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870.§§Richardson, J. H. 3 Arundel-terrace, Cork.
1868.§§Richardson, James C. Glanrafon, near Swansea.
1863. ‡Richardson, John W. South Ashfield, Newcastle-on-Tyne.
1870. §Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
Richardson, William. Micklegate, York.
1861. §Richardson, William. 4 Edward-street, Werneth, Oldham.
1861. ‡Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.
1863. ‡Richter, Otto, Ph.D. 7 India-street, Edinburgh.
1870.§§Rickards, Dr. 36 Upper Parliament-street, Liverpool.
1868. §Ricketts, Charles, M.D., F.G.S. 22 Argyle-street, Birkenhead.
*Riddell, Major-General Charles J. Buchanan, C.B., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1859. ‡Riddell, Rev. John. Moffat by Beatlock, N. B.
1861. *Rideout, William J. 51 Charles-street, Berkeley-square, London, W.
1862. ‡Ridgway, Henry Akroyd, B.A. Bank Field, Halifax.
1861. §Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. ‡Ridley, Samuel. 7 Regent's-terrace, Newcastle-on-Tyne.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
1860. ‡Ritchie, George Robert. 4 Watkyn-Terrace, Coldharbour-lane, Camberwell, London.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1853. ‡Rivay, John V. C. 19 Cowley-street, London, S.W.
1869. *Rivington, John. 14 Porchester-terrace, Hyde Park, London, W.
1854. ‡Robberds, Rev. John, B.A. Ashlar House, Battledown, Cheltenham.
1869. *Robbins, J. 372 Oxford-street, London, W.
Roberton, John. Oxford-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F.S.A. Athenæum Club, London, S.W.
1870. *Roberts, Isaac, F.G.S. 26 Rock-park, Rock Ferry, Cheshire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
*Roberts, William P. 38 Red Lion-square, London, W.C.
1868. §Roberts, W. Chandler, F.G.S., F.C.S. Royal Mint, London, E.C.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1866. §Robertson, Alister Stuart, M.D., F.R.G.S. Horwich, Bolton, Lancashire.
1867. §Robertson, David. Union Grove, Dundee.
1871. §Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. Bank, High-street, Manchester.
1866. ‡Robertson, William Tindal, M.D. Nottingham.
1861. §Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1864. ‡*Robinson, George Augustus.*
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
1860. ‡*Robinson, Professor H. D.*
*Robinson, H. Oliver. 194 West George-street, Glasgow.
1866. ‡Robinson, John. Museum, Oxford.
1861. ‡Robinson, John. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.

Year of Election.

1855. ‡Robinson, M. E. 116 St. Vincent-street, Glasgow.
1860. ‡Robinson, Admiral Robert Spencer. 61 Eaton-place, London, S.W.
Robinson, Rev. Thomas Romney, D.D., F.R.S., F.R.A.S., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. §Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 17 Falkner-square, Liverpool.
1863. **Robson, James.*
*Robson, Rev. John, M.A., D.D Ajmére Lodge, Cathkin-road, Langside, Glasgow.
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1851. ‡Rodwell, William. Woodlands, Holbrook, Ipswich.
1866. ‡Roe, Thomas. Grove Villas, Sitchurch.
1846. ‡Roe, William Henry. Portland-terrace, Southampton.
1861. §Rofe, John, F.G.S. 7 Queen-street, Lancaster.
1869. *Rogers, Nathaniel, M.D. 34 Paul-street, Exeter.
1860. ‡Rogers, James E. Thorold, Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1870.§§Rogers, T. L., M.D. Rainhill, Liverpool.
1859. ‡Rolleston, George, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.
1863. ‡Romilly, Edward. 14 Hyde Park-terrace, London, W.
1845. ‡Ronalds, Sir Francis, F.R.S. 9 St. Mary's-villas, Battle, Sussex.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1865. ‡Roper, R. S., F.G.S. Cwmbrae Iron Works, Newport, Monmouthshire.
1861. *Roscoe, Henry Enfield, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1861. ‡Rose, C. B., F.G.S. 25 King-street, Great Yarmouth, Norfolk.
1863. ‡Roseby, John. Haverholme House, Brigg, Lincolnshire.
1857. ‡Ross, David, LL.D. Drumbrain Cottage, Newbliss, Ireland.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1861. *Ross, Thomas. 7 Wigmore-street, Cavendish-square, London, W.
1842. Ross, William. Pendleton, Manchester.
1869. *Rosse, The Right Hon. The Earl of, D.C.L., F.R.S., F.R.A.S. Birr Castle, Parsonstown, Ireland.
1855. ‡Roth, Dr. Matthias. 16A Old Cavendish-street, London, W.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1849.§§Round, Daniel G. Hange Colliery, near Tipton, Staffordshire.
1847. ‡Rouse, William. 16 Canterbury Villas, Maida Vale, London, W.
1861. ‡Routh, Edward J., M.A. St. Peter's College, Cambridge.
1861. §Rowan, David. Elliot-street, Glasgow.
1855. ‡Rowand, Alexander. Linthouse, near Glasgow.
1865. §Rowe, Rev. John. Beaufort-villas, Edgbaston, Birmingham.
1855. *Rowney, Thomas H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
*Rowntree, Joseph. Leeds.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1859. ‡*Ruland, C. H.*
1869.§§Rudler, F. W., F.G.S. 6 Pond-street, Hampstead, London, N.W.
1861. *Rumney, Robert, F.C.S. Springfield, Whalley Range, Manchester.
1856. ‡Rumsay, Henry Wildbore. Gloucester Lodge, Cheltenham.

Year of
Election.

1847. ‡Ruskin, John, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Denmark-hill, London, S.E.
1857. ‡Russell, Rev. C. W., D.D. Maynooth College.
1855. ‡Russell, James, jun. Falkirk.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
1859. ‡Russell, John, the Right Hon. Earl, K.G., F.R.S., F.R.G.S. 37 Chesham-place, Belgrave-square, London, S.W.
Russell, John. 15 Middle Gardiner's-street, Dublin.
Russell, John Scott, M.A., F.R.S. L. & E. Sydenham; and 5 Westminster Chambers, London, S.W.
1852. *Russell, Norman Scott. 5 Westminster Chambers, London, S.W.
1863. ‡Russell, Robert. Gosforth Colliery, Newcastle-on-Tyne.
1852. *Russell, William J., Ph.D., Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London.
1862. §Russell, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.
1865. ‡Rust, Rev. James, M.A. Manse of Slains, Ellon, N. B.
1871. §Rutherford, William, M.D., Professor of Physiology in King's College, London, W.C.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1871. §Ruttledge, T. E. 28 Finsbury-square, London, E.C.
1852. ‡*Ryan, John, M.D.*
*Ryland, Arthur. The Linthurst, Broomsgrove, near Birmingham.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1853. ‡Rylands, Joseph. 9 Charlotte-street, Hull.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

*Sabine, General Sir Edward, K.C.B., R.A., LL.D., D.C.L., President of the Royal Society, F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865. ‡Sabine, Robert. 3 Delahay-street, London, S.W.
1871. §Sadler, Samuel Camperdowne. Purton Court, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1848. ‡St. Davids, The Right Rev. Connop Thirlwall, D.D., F.G.S., Lord Bishop of. Abergwili, Carmarthen.
Salkeld, Joseph. Penrith, Cumberland.
1857. ‡Salmon, Rev. George, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1864. ‡*Salmon, Henry C., F.G.S., F.C.S.*
1858. *Salt, Sir Titus, Bart. Methley Park, near Leeds.
1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.
1861. *Samson, Henry. Messrs. Samson and Leppoc, 6 St. Peter's-square, Manchester.
1867. ‡Samuelson, Edward. Roby, near Liverpool.
1870. §§Samuelson, James. St. Domingo-grove, Everton, Liverpool.
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1857. ‡Sanders, Gilbert. The Hill, Monkstown, Co. Dublin.
*Sanders, William, F.R.S., F.G.S. Hanbury Lodge, The Avenue, Clifton, Bristol.
1871. §Sanders, William R., M.D. 11 Walker-street, Edinburgh.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, Right Hon. Lord, M.P. 39 Gloucester-square, London, W
1865. ‡Sargant, W. L. Edmund-street, Birmingham.

Year of Election.

Satterfield, Joshua. Alderley Edge.
1861. ‡Saul, Charles J. Smedley-lane, Cheetham-hill, Manchester.
1868. ‡Saunders, A., C.E. King's Lynn.
1846. ‡Saunders, Trelawney W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1863. ‡Savory, Valentine. Cleckheaton, near Leeds.
1868.§§Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1857. ‡Scallan, James Joseph. 77 Harcourt-street, Dublin.
1850. ‡Scarth, Pillans. 2 James's-place, Leith.
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
*_Schemman, J. C. Hamburg._
*Schlick, Count Benj. Quai Voltaire, Paris.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
*Scholes, T. Seddon. Irlam Lodge, Warwick-place, Leamington.
1847. *Scholey, William Stephenson, M.A. Freemantle Lodge, Bath-road, Reading.
Schunck, Edward, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1861. *Schwabe, Edmund Salis. Rhodes House, near Manchester.
1867. ‡_Schwendler, Louis._
1847. ‡Sclater, Philip Lutley, M.A, Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. 11 Hanover-square, London, W.
1867. ‡Scott, Alexander. Clydesdale Bank, Dundee.
1871. §Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1865. §Scott, Major-General E. W. S., Royal Bengal Artillery. Treledan Hall, Welshpool, Montgomeryshire.
1859. ‡Scott, Captain Fitzmaurice. Forfar Artillery.
1871. §Scott, James S. T. Monkrigg, Haddingtonshire.
1855. ‡Scott, Montague D., B.A. Hove, Sussex.
1857. §Scott, Robert H., M.A., F.R.S., F.G.S., Director of the Meteorological Office, 116 Victoria-street, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 14 Victoria-crescent, Dowanhill, Glasgow.
1864. ‡Scott, Wentworth Lascelles. Wolverhampton.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. §Scott, William Bower. Chudleigh, Devon.
1864. ‡Scott, William Robson, Ph.D. St. Leonards, Exeter.
1869.§§Searle, Francis Furlong. 5 Cathedral Yard, Exeter.
1859. ‡Seaton, John Love. Hull.
1870. §Seaton, Joseph, M.D. Halliford House, Sandbury.
*Sedgwick, Rev. Adam, M.A., LL.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., F.R.G.S., Woodwardian Professor of Geology in the University of Cambridge, and Canon of Norwich. Trinity College, Cambridge.
1861. *Seeley, Harry Govier, F.G.S. St. John's College, Cambridge.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
*Selwyn, Rev. Canon William, M.A., D.D., F.R.S., Margaret Professor of Divinity in the University of Cambridge. Vine Cottage, Cambridge.
1858. *Senior, George, F.S.S. Rose Hill, Dodsworth, near Barnsley.
1870. *Sephton, Rev. J. Liverpool Institute, Mount-street, Liverpool.
1868. ‡Sewell, Philip E. Catton, Norwich.
Seymour, George Hicks. Stonegate, York.
1861. *Seymour, Henry D. Athenæum Club, Pall Mall, London, S.W.
Seymour, John. 21 Bootham, York.

Year of Election.

1853. ‡Shackles, G. L. 6 Albion-street, Hull.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, S.W.
1871. *Shand, James. Eliot Bank, Sydenham-hill, London, S.E.
1867. §Shanks, James. Den Iron Works, Arbroath, N. B.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡Sharp, Samuel, F.G.S., F.S.A. Dallington Hall, near Northampton.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
Sharpey, William, M.D., LL.D., Sec. R.S., F.R.S.E., Professor of Anatomy and Physiology in University College. Lawnbank, Hampstead, London, N.W.
1869. *Shapter, Lewis. The Barnfield, Exeter.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. §Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. §Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1861. *Shaw, John. City-road, Hulme, Manchester.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
Shepard, John. Nelson-square, Bradford, Yorkshire.
1863. ‡Shepherd, A. B. New University Club, St. James's-street, London, S.W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1869. *Shepperd, Alfred Bayard. Torquay.
1869. ‡Sherard, Rev. S. H. Newton Abbot, Devon.
1851. ‡Shewell, John T. Rushmere, Ipswich.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. §Shinn, William C. (Assistant General Treasurer). Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1864. ‡*Showers, Lieut.-Colonel Charles L. Cox's Hotel, Jermyn-street, London, S.W.*
1870. *Shoolbred, James N. York-buildings, Dale-street, Liverpool.
1842. Shuttleworth, John. Wilton Polygon, Cheetham-hill, Manchester.
1866. ‡Sibson, Francis, M.D., F.R.S. 59 Brook-street, Grosvenor-square, London, W.
1861. *Sidebotham, Joseph. 19 George-street, Manchester.
1861. *Sidebottom, James. Mersey Bank, Heaton Mersey, Manchester.
1857. ‡Sidney, Frederick John. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1856. §Siemens, C. William, D.C.L., F.R.S. 3 Great George-street, London, S.W.
*Sillar, Zechariah, M.D. Bath House, Laurie Park, Sydenham, London, S.E.
1859. ‡Sim, John. Hardgate, Aberdeen.
1855. ‡Sim, William. Furnace, near Inverary.
1871. §Sime, James. Craigmount House, Grange, Edinburgh.
1865. §§Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1852. ‡Simms, William. Albion-place, Belfast.
1847. ‡Simon, John, D.C.L., F.R.S. 40 Kennington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *Simpson, Alexander R., M.D., Professor of Midwifery in the University of Edinburgh.

Year of Election.

1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Marykirk, Kincardineshire.
1863.§§Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡Simpson, Maxwell, M.D., F.R.S., F.C.S. 1 Brougham-place, Dublin.
*Simpson, Rev. Samuel. Greaves House, near Lancaster.
Simpson, Thomas. Blake-street, York.
Simpson, William. Bradmore House, Hammersmith, London, W.
1859. ‡Sinclair, Alexander. 133 George-street, Edinburgh.
1834. ‡Sinclair, Vetch, M.D. 4 Picardy-place, Edinburgh.
1870. *Sinclair, W. P. 32 Devonshire-roads, Prince's-park, Liverpool.
1864. *Sircar, Baboo Mohendro Lall, M.D. 1344 San Kany, Tollah-street, Calcutta, per Messrs. Harrenden & Co., 3 Chaple-place, Poultry, London, E.C.
1865. §Sissons, William. 92 Park-street, Hull.
1850. ‡Skae, David, M.D. Royal Asylum, Edinburgh.
1870. §Sladen, Walter Percy. Exley House, near Halifax.
1870. §Slater, W. B. 28 Hamilton-square, Birkenhead.
1842. *Slater, William. 75 Princes-street, Manchester.
1853. §Sleddon, Francis. 2 Kingston-terrace, Hull.
1849.§§Sloper, George Edgar, jun. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §Sloper, S. Elgar. Winterton, near Southampton.
1867. ‡Small, David. Gray House, Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1867. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1868.§§Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey.
1857. ‡Smith, Aquila, M.D., M.R.I.A. 121 Lower Bagot-street, Dublin.
Smith, Archibald, M.A., LL.D., F.R.S. L. & E. River-bank, Putney; and 3 Stone-buildings, Lincoln's Inn, London, W.C.
Smith, Rev. B., F.S.A.
1865. §Smith, David, F.R.A.S. 4 Cherry-street, Birmingham.
1853. ‡Smith, Edmund. Ferriby, near Hull.
1859. ‡Smith, Edward, M.D., LL.B., F.R.S. 140 Harley-street, London, W.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
*Smith, Rev. George Sidney, D.D., M.R.I.A., Professor of Biblical Greek in the University of Dublin. Riverland, Omagh, Ireland.
*Smith, Henry John Stephen, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford. 64 St. Giles's, Oxford.
1860. *Smith, Heywood, M.A., M.B. 2 Portugal-street, Grosvenor-square, London, W.
1865. ‡Smith, Isaac. 26 Lancaster-street, Birmingham.
1870.§§Smith, James. 146 Bedford-street South, Liverpool.
1842. *Smith, James. Berkeley House, Seaforth, near Liverpool.
1855. ‡Smith, James. St. Vincent-street, Glasgow.
1853. ‡Smith, John. York City and County Bank, Malton, Yorkshire.
1871. *Smith, John Alexander, M.D. 7 West Maitland-street, Edinburgh.
1858. *Smith, John Metcalf. Old Bank, Leeds.
1867. §Smith, John P., C.E. 67 Renfield-street, Glasgow.
Smith, John Peter George. Spring Bank, Anfield, Liverpool.
1852. *Smith, Rev. Joseph Denham. Bellevue, Blackrock, Co. Dublin.

Year of
Election.

1861. ‡Smith, Professor J., M.D. University of Sydney, Australia.
*Smith, Philip, B.A. 4 Cambridge-terrace, Junction-road, London, N.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §Smith, Robert Angus, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870.§§Smith, Samuel. Bank of Liverpool, Liverpool.
1866. §Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1867. ‡Smith, Thomas (Sheriff). Dundee.
1867. §Smith, Thomas. Pole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1857. §Smith, William, C.E., F.G.S., F.R.G.S. 19 Salisbury-street, Adelphi, London, W.C.
1871. §Smith, William Robertson. Aberdeen.
1850. *Smyth, Charles Piazzi, F.R.S. L. & E., F.R.A.S., Astronomer Royal for Scotland, Professor of Practical Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1870. §Smyth, Colonel H. A., R.A. 25 Inverness-road, Bishop's-road, London, W.
1870.§§Smyth, H. L. Crabwall Hall, Cheshire.
1857. *Smyth, John, jun., M.A., M.I.C.E.I., F.M.S. Milltown, Banbridge, Ireland.
1868. ‡Smyth, Rev. J. D. Hurst. 13 Upper St. Giles's-street, Norwich.
1864. ‡Smyth, Warington W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 13 Victoria-street, London, S.W.
1854. ‡Smythe, Colonel W. J., R.A., F.R.S. Bombay.
Soden, John. Athenæum Club, Pall Mall, London, S.W.
1853. ‡Sollitt, J. D., Head Master of the Grammar School, Hull.
*Solly, Edward, F.R.S., F.L.S., F.G.S., F.S.A. Sandecotes, near Poole
*Sopwith, Thomas, M.A., F.R.S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, S.W.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *Sorby, H. Clifton, F.R.S., F.G.S. Broomfield, Sheffield.
1865. *Southall, John Tertius. Leominster.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Greenbank, Darlington.
1859. ‡Spence, Rev. James, D.D. 6 Clapton-square, London, N.E.
*Spence, Joseph. 60 Holgate Hill, York.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
1861.§§Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. 27 Brown-street, Manchester.
1863. *Spencer, Thomas. The Grove Ruban, near Blaydon-on-Tyne.
1855. ‡Spens, William. 78 St. Vincent-street, Glasgow.
1871. §Spicer, George. Broomfield, Halifax.
1864. *Spicer, Henry, jun., F.G.S. 22 Highbury-crescent; and 19 New Bridge-street, Blackfriars, London, E.C.

Year of
Election.

1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1847. *Spiers, Richard James, F.S.A. 14 St. Giles's-street, Oxford.
1868. *Spiller, Edmund Pim. 3 Furnival's Inn, London, E.C.
1864. *Spiller, John, F.C.S. 35 Grosvenor-road, Highbury New Park, London, N.
1846. *Spottiswoode, William, M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. (General Treasurer). 50 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 50 Grosvenor-place, London, S.W.
1854. *Sprague, Thomas Bond. 4 Lansdowne-place, Blackheath, London, S.E.
1853. ‡Spratt, Joseph James. West Parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.
1859. ‡Stables, William Alexander. Cawdor Castle, Nairn, N.B.
1858. *Stainton, Henry T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, Kent.
1851. *Stainton, James Joseph, F.L.S., F.C.S. Meadowcroft, Lewisham, London, S.E.
1865. §Stanford, Edward C. C. Edinbarnet, Dumbartonshire.
Stanley, The Very Rev. Arthur Penrhyn, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.
Stapleton, H. M. 1 Mountjoy-place, Dublin.
1866. §Starey, Thomas R. Daybrook House, Nottingham.
1863. ‡Stark, Richard M. Hull.
Staveley, T. K. Ripon, Yorkshire.
1857. ‡Steel, William Edward, M.D. 15 Hatch-street, Dublin.
1863. §Steele, Rev. Dr. 2 Bathwick-terrace, Bath.
1861. ‡Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
Stenhouse, John, LL.D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1870. §§Stearn, C. H. 3 Elden-terrace, Rock Ferry, Liverpool.
1861. *Stern, S. J. Rusholme House, Manchester.
1863. §Sterriker, John. Driffield.
1870. *Stevens, Miss Anna Maria. Wiley, near Salisbury.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1863. *Stevenson, Archibald. South Shields.
1850. ‡Stevenson, David. 8 Forth-street, Edinburgh.
1868. ‡Stevenson, Henry, F.L.S. 10 Unthank-road, Norwich.
1863. *Stevenson, James C. Westoe, South Shields.
1855. Stewart, Balfour, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester. Owens College, Manchester.
1864. ‡Stewart, Charles, F.L.S. 19 Princess Square, Plymouth.
1856. *Stewart, Henry Hutchinson, M.D., M.R.I.A. 71 Eccles-street, Dublin.
1869. §Stewart, J. L. East India United Service Club, 14 St. James's-square, London, S.W.
1847. ‡Stewart, Robert, M.D. The Asylum, Belfast.
1867. ‡Stirling, Dr. D. Perth.
1868. §Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1867. *Stirrup, Mark. 2 Harwood-place, Old Trafford, Manchester.
1865. *Stock, Joseph S. Showell Green, Spark Hill, near Birmingham.
1862. ‡Stockil, William. 5 Church Meadows, Sydenham, London, S.E.
Stoddart, George. 11 Russell-square, London, W.C.
1864. §Stoddart, William Walter, F.G.S., F.C.S. 7 King-square, Bristol.
1854. ‡Stoess, Le Chevalier, Ch. de W. (Bavarian Consul). Liverpool.

Year of Election.

*Stokes, George Gabriel, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambrdge. Lensfield Cottage, Lensfield-road, Cambridge.
1862. ‡Stone, Edward James, M.A., F.R.S., F.R.A.S., Astronomer Royal at at the Cape of Good Hope. Cape Town.
1859. ‡Stone, Dr. William H. 13 Vigo-street, London, W.
1857. ‡Stoney, Bindon B., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1861. *Stoney, George Johnstone, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 40 Wellington-road, Dublin.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1867.§§Storrar, John, M.D. Heathview, Hampstead, London, N.W.
1859. §Story, James. 17 Bryanston-square, London, W.
1863. ‡Strachan, T. Y. Lovaine-crescent, Newcastle-on-Tyne.
1871. *Strachey, Major-General, R.E., F.R.S. 8 Rutland-gate, London, S.W.
1863. ‡Straker, John. Wellington House, Durham.
1868.§§Strange, Lieut.-Colonel A., F.R.S., F.R.A.S., F.R.G.S. India Stores, Belvedere-road, Lambeth, London, S.E.
*Strickland, Charles. Loughglyn House, Castherea, Ireland.
Strickland, William. French-park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867.§§Stronner, D. 14 Princess-street, Dundee.
1866. *Strutt, The Hon. Arthur, F.G.S. Duffield, near Derby.
1868. *Strutt, The Hon. John W. Terling-place, Witham, Essex.
1861. ‡*Stuart, W. D. Philadelphia.*
1866. ‡*Stubbins, Henry.*
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1857. ‡Sullivan, William K., Ph.D., M.R.I.A. Museum of Irish Industry; and 53 Upper Leeson-road, Dublin.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *Sutherland, George Granville William, Duke of, K.G., F.R.G.S. Stafford House, London, S.W.
1855. ‡Sutton, Edwin. 44 Winchester-street, Pimlico, London, S.W.
1863.§§Sutton, Francis, F.C.S. Bank Plain, Norwich.
1861. *Swan, Patrick Don S. Kirkaldy, N.B.
1862. *Swan, William, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. 2 Hope-street, St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke. Gedling, near Nottingham.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburn, Sir John. Capheaton, Newcastle-on-Tyne.
1863.§§Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1863.§§Swinhoe, Robert, F.R.G.S. 33 Oakley-square, S.W.; and Oriental Club, London, W.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
*Sykes, Colonel William Henry, M.P., F.R.S., Hon. M.R.I.A., F.G.S., F.R.G.S. 47 Albion-street, Hyde Park, London, W.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London. W.
Sylvester, James Joseph, M.A., LL.D., F.R.S., 60 Maddox-street, W., and Athenæum Club, London, S.W.
1870. §Symes, Richard G., F.G.S. 14 Hume-street, Dublin.
1856. *Symonds, Frederick, F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡Symonds, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §Symons, G. J., F.M.S. 62 Camden-square, London, N.W.
1855. *Symons, William, F.C.S. 26 Joy-street, Barnstaple.

Year of Election.

Synge, Rev. Alexander. St. Peter's, Ipswich.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
Synge, John Hatch. Glanmore, Ashford, Co. Wicklow.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N. B.
1871. §Tait, Peter Guthrie, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. 17 Drummond-place, Edinburgh.
1867. ‡Tait, P. M., F.R.G.S. 26 Adelaide Road, N.; and Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire.
Talbot, William Henry Fox, M.A., LL.D., F.R.S., F.L.S. Lacock Abbey, near Chippenham.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London, W.
1866. ‡Tarbottom, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1861. *Tarratt, Henry W. Bushbury Lodge, Leamington.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1864. ‡*Tasker, Rev. J. C. W.*
1857. *Tate, Alexander. 2 Queen's Elms, Belfast.
1863. Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. §§Tate, Norman A. 7 Nivell Chambers, Fazackerley-street, Liverpool.
1865. ‡Tate, Thomas. White Horse Hill, Chislehurst, Kent.
1858. *Tatham, George. Springfield Mount, Leeds.
1864. *Tawney, Edward B., F.G.S. Ashbury Dale, Torquay.
1871. §Tayler, William, F.S.A., F.S.S. 28 Park-street, Grosvenor-square, London, W.
1867. ‡Taylor, Rev. Andrew. Dundee.
Taylor, Frederick. Laurel-cottage, Rainhill, near Prescot, Lancashire.
*Taylor, James. Culverlands, near Reading.
*Taylor, John, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, London, E.C.
1863. ‡Taylor, John. Earsdon, Newcastle-on-Tyne.
1863. ‡Taylor, John. Lovaine-place, Newcastle-on-Tyne.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
Taylor, Captain P. Meadows, in the Service of His Highness the Nizam. Harold Cross, Dublin.
*Taylor, Richard, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1870. §Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
Taylor, Rev. William, F.R.S., F.R.A.S. Thornloe, Worcester.
*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. ‡Teale, Joseph. Leeds.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1869. ‡Teesdale, C. S. M. Pennsylvannia, Exeter.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*Tennant, James, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1849. ‡Teschemacher, E. F. Highbury-park North, London, N.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1859. ‡Thain, Rev. Alexander. New Machar, Aberdeen.
1871. §Thin, James. Rillbank-terrace, Edinburgh.
1871. §Thiselton-Dyer, W. T., B.A., B.Sc., Professor of Botany in the Royal College of Science for Ireland, Dublin.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. §§Thom, Robert Wilson. Lark Hill, Chorley, Lancashire.

Year of
Election.

1871. §Thomas, Arcanius William Nurli. Chudleigh, Devon.
Thomas, George. Brislington, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1869. §Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
*Thompson, Corden, M.D. Norfolk-street, Sheffield.
1863. ‡Thompson, Rev. Francis. St. Giles's, Durham.
1858. *Thompson, Frederick. South Parade, Wakefield.
1859.§§Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Woodlands, Wilmslow, near Manchester.
1864.§§Thompson, Rev. Joseph Hesselgrave, B.A. Cradley, near Brierley-hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
1853. ‡Thompson, Thomas (Austrian Consul). Hull.
Thompson, Thomas (Town Clerk). Hull.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen Yard-road, Dundee.
1855. ‡Thomson, Allen, M.D., LL.D., F.R.S., Professor of Anatomy in the University of Glasgow.
1867. ‡Thomson, Francis Hay, M.D. Glasgow.
1852. ‡Thomson, Gordon A. Bedeque House, Belfast.
Thomson, Guy. Oxford.
1870.§§Thomson, Sir Henry, M.D. 35 Wimpole-street, London. W.
1855. ‡Thomson, James. 82 West Nile-street, Glasgow.
1850. *Thomson, Professor James, M.A., LL.D., C.E. 17 University-square, Belfast.
1868. §Thomson, James, F.G.S. 276 Eglington-street, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1871. *Thomson, John Millar. King's College, London, W.C.
1863. ‡Thomson, M. 8 Meadow-place, Edinburgh.
1871. §Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh,
1865. ‡Thomson, R. W., C.E., F.R.S.E. 3 Moray-place, Edinburgh.
1847. *Thomson, Sir William, M.A., LL.D., D.C.L., F.R.S. L. & E., President, Professor of Natural Philosophy in the University of Glasgow. The College, Glasgow.
1850. ‡Thomson, Thomas, M.D., F.R.S., F.L.S. (General Secretary). Kew Green, Kew.
1871. §Thomson, William Burnes. 11 St. John's-street, Edinburgh.
1870.§§Thomson, W. C., M.D. 7 Domingo Vale, Everton, Liverpool.
1850. ‡Thomson, Wyville T. C., LL.D., F.R.S., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
1871. §Thorburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thorburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1865. *Thornley, S. Gilbertstone House, Bickenhill, near Birmingham.
1866. ‡Thornton, James. Edwalton, Nottingham.
*Thornton, Samuel. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Suffolk Laun, Cheltenham.
1871. §Thorp, Henry. Whalley Range, Manchester.
*Thorp, The Venerable Thomas, B.D., F.G.S., Archdeacon of Bristol. Kemerton, near Tewkesbury.
1864. *Thorp, William, jun., F.C.S. 39 Sandringham-road, West Hackney, London, N.E.
1871. §Thorpe, T. E., Professor of Chemistry, Andersonian University, Glasgow. The College, Glasgow.

Year of Election.

1868. ‡Thuillier, Colonel. 27 Lower Seymour-street, Portman-square, London, W.

Thurnam, John, M.D. Devizes.

1870. §Tichborne, Charles R. S., F.C.S. Apothecaries' Hall of Ireland, Dublin.

1865.§§Timmins, Samuel. Elvetham-road, Edgbaston, Birmingham.

Tinker, Ebenezer. Mealhill, near Huddersfield.

*Tinné, John A., F.R.G.S. Briarly, Aigburth, Liverpool.

Tite, Sir William, M.P., F.R.S., F.G.S., F.S.A. 42 Lowndes-square, London, S.W.

1859. ‡Todd, Thomas. Mary Culter House, Aberdeen.

1861. *Todhunter, Isaac, M.A., F.R.S. Principal Mathematical Lecturer of St. John's College, Cambridge. Bourne House, Cambridge.

Todhunter, J. 3 College Green, Dublin.

1857. ‡Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.

1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.

1864. *Tomlinson, Charles, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.

1863. ‡Tone, John F. Jesmond Villas, Newcastle-on-Tyne.

1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.

1865. §Tonks, William Henry. 4 Carpenter-road, Edgbaston, Birmingham.

1861. *Topham, John, A.I.C.E. High Elms, Hackney, London, N.E.

1863. ‡Torr, F. S. 38 Bedford-row, London, W.C.

1863. ‡Torrens, R. R., M.P. 2 Gloucester-place, Hyde Park, London, W.

1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.

Towgood, Edward. St. Neots, Huntingdonshire.

1860. ‡Townsend, John. 11 Burlington-street, Bath.

1857. ‡Townsend, Rev. Richard, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.

1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.

1854. ‡Towson, John Thomas, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.

1859. ‡Trail, Rev. Robert, M.A. Boyndie, Banff.

1859. ‡Trail, Samuel, D.D., LL.D. The Manse, Hanay, Orkney.

1870. §Traill, William A. Geological Survey of Ireland, 14 Hume-street, Dublin.

1868. §Traquair, Ramsay H., M.D., Professor of Zoology, Royal College of Science, Dublin.

1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.

1859. ‡*Trefusis, The Hon. C.*

Tregelles, Nathaniel. Neath Abbey, Glamorganshire.

1868. §Trehane, John. Exe View Lawn, Exeter.

1869. ‡Trehane, John, jun. Bedford-circus, Exeter.

1870.§§Trench, Dr. Municipal Offices, Dale-street, Liverpool.

Trench, F. A. Newlands House, Clondalkin, Ireland.

*Trevelyan, Arthur. Tyneholme Tranent, Haddingdonshire.

Trevelyan, Sir Walter Calverley, Bart., M.A., F.R.S.E., F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.

1871. §Tribe, Alfred. 73 Artesian-road, Bayswater, London.

1871. §Trimen, Roland, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.

1860. §Tristram, Rev. Henry Baker, M.A., LL.D., F.R.S., F.L.S. Greatham Hospital, near Stockton-on-Tees.

1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.

1864. ‡Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.

Year of Election.

1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Balwin-street, Bristol.
Tuckett, Frederick. 4 Mortimer-street, Cavendish-square, London, W.
Tuke, James H. Bank, Hitchen.
1871. §Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1865. §Turbervile, H. Pilton, Barnstaple.
1854. ‡Turnbull, James, M.D. 86 Rodney-street, Liverpool.
1855. §Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill Villas, Cheltenham.
*Turnbull, Rev. Thomas Smith, M.A., F.R.S., F.G.S., F.R.G.S. Blofield, Norfolk.
1871. §Turnbull, William. 14 Lansdowne-crescent, Edinburgh.
Turner, Thomas, M.D. 31 Curzon-street, May Fair, London, W.
1863. *Turner, William, M.B., F.R.S.E., Professor of Anatomy in the University of Edinbugh. 6 Eaton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. 11 Regent's Park-road, London, N.W.
1859. ‡Twining, H. R. Grove Lodge, Clapham, London, S.W.
1847. ‡Twiss, Sir Travers, D.C.L., F.R.S., F.R.G.S., Regius Professor of Civil Law in the University of Oxford, and Chancellor of the Diocese of London. 19 Park-lane, London, W.
1846. ‡Tylor, Alfred, F.G.S. 2 Newgate-street, London, E.C.
1865. §Tylor, Edward Burnett. Lindon, Wellington, Somerset.
1858. *Tyndall, John, LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. Seedley-road, Pendleton, near Manchester.

1855. ‡Ure, John. 114 Montrose-street, Glasgow.
1859. ‡Urquhart, Rev. Alexander. Tarbat, Ross-shire.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N. B.; and Castlepollard, Ireland.
1866. §Urquhart, William W. Bosebay, Broughty Ferry, by Dundee.

1870. §§Vale, H. H. 42 Prospect Vale, Fairfield, Liverpool.
1854. ‡*Vale, James Theodorick. Hamilton-square, Birkenhead.*
*Vallack, Rev. Benjamin W. S. St. Budeaux, near Plymouth.
*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M Tunisienne, Geneva.
1853. §Varley, Cornelius. 337 Kentish Town-road, London, N.W.
1854. ‡*Varley, Cromwell F.*
1868. §Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay Avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. 66 Roman-road, Holloway, London, N.
1870. §Varley, Mrs. S. A. 66 Roman-road, Holloway-road, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1863. ‡Vauvert, de Mean A., Vice-Consul for France. Tynemouth.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
1854. *Vernon, George V., F.R.A.S. 1 Osborne-place, Old Trafford, Manchester.
1854. *Vernon, John. Gateacre, Liverpool.

Year of
Election.

1864. *Vicary, William, F.G.S. The Priory, Colleton-crescent, Exeter.
1854. *Vignoles, Charles B., C.E., F.R.S., M.R.I.A., F.R.A.S., V.P.I.C.E 21 Duke-street, Westminster, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1856. ‡Vivian, Edward, B.A. Woodfield, Torquay.
*Vivian, H. Hussey, M.P., F.G.S. Park Wern, Swansea; and 7 Belgrave-square, London, S.W.
1856. §Voelcker, J. Ch. Augustus, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1860.§§Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡Waddington, John. New Dock Works, Leeds.
1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.
1870.§§Waley, Jacob. 20 Wimpole-street, London, W.
1869. *Walford, Cornelius. Enfield House, Belsize Park Gardens, London, N.W.
1870. §Wake, Charles Staniland. 4 St. Martin's-place, Trafalgar-square, London, W.C.
1863. ‡*Walker, Alfred O.*
1849. §Walker, Charles V., F.R.S., F.R.A.S. Fernside Villa, Redhill, near Reigate.
Walker, Sir Edward S. Berry Hill, Mansfield.
Walker, Francis, F.L.S., F.G.S. Elm Hall, George-lane, Wanstead, London, N.
Walker, Frederick John. The Priory, Bathwick, Bath.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1859. ‡Walker, James. 16 Norfolk-crescent, London, W.
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1842. *Walker, John. Thorncliffe, New Kenilworth-road, Leamington.
1866. *Walker, J. F. Sidney College, Cambridge.
1867. *Walker, Peter G. Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1869. *Walker, Thomas F. W., M.A., F.R.G.S. 6 Brock-street, Bath.
Walker, William. 47 Northumberland-street, Edinburgh.
1869. ‡Walkey, J. E. C. High-street, Exeter.
Wall, Rev. R. H., M.A. 6 Hume-street, Dublin.
1863. §Wallace, Alfred R., F.R.G.S. Holly House, Barking, Essex.
1859. ‡Wallace, William, Ph.D., F.C.S. Chemical Laboratory, 3 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡Wallich, George Charles, M.D., F.L.S. 11 Earls-terrace, Kensington, London, W.
Wallinger, Rev. William. Hastings.
Walmsley, Sir Joshua, Knt.
1862. ‡Walpole, The Right Hon. Spencer Horatio, M.A., D.C.L., M.P., F.R.S. Ealing, near London.
1857. ‡Walsh, Albert Jasper. 89 Harcourt-street, Dublin.
Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred, F.R.S.E., F.C.S. 3 Great Winchester street-buildings, London, E.C.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.

Year of Election.

1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 55 Parliament-street, London, S.W.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1869. §Warren, James L. Letterfrack, Galway.
1865. *Warren, Edward P., L.D.S. 13 Old-square, Birmingham.
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
*Waterhouse, John, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1854. ‡Waterhouse Nicholas. 5 Rake-lane, Liverpool.
1870. §§Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorn House, Cringleford, Norwich.
*Watson, Henry Hough, F.C.S. 227 The Folds, Bolton-le-Moors.
Watson, Hewett Cottrell. Thames Ditton, Surrey.
1855. ‡Watson, James, M.D. 152 St. Vincent-street, Glasgow.
1859. ‡Watson, John Forbes, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham Grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. §Watson, Thomas D. 18 A Basinghall-street, London, E.C.
1858. ‡Watson, William. Bilton House, Harrogate.
1869. ‡Watt, Robert B. E. Ashby-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1846. §§Watts, John King, F.R.G.S. St. Ives, Huntingdonshire.
1870. §Watts, William. Corporation Waterworks, Swineshaw, Staleybridge.
1858. ‡Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1862. §Waugh, Major-General Sir Andrew Scott, R.E., F.R.S., F.R.A.S., F.R.G.S., late Surveyor-General of India, and Superintendent of the Great Trigonometrical Survey. 7 Petersham-terrace, Queen's Gate-gardens, London, W.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
*Way, J. Thomas, F.C.S., 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1871. §Webb, Richard M. 72 Grand Parade, Brighton.
*Webb, Rev. Thomas William, M.A., F.R.A.S. Hardwick Parsonage, Hay, South Wales.
1866. *Webb, William Frederick, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1856. ‡Webster, James. Hatherley Court, Cheltenham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1862. ‡Webster, John Henry, M.D. Northampton.
1864. §Webster, John. Belvoir-terrace, Sneinton, Nottingham.
Webster, Thomas, M.A., F.R.S. 2 Pump Court, Temple, London, E.C.
1845. ‡Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park, London, N.W.
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.

Year of Election.

1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1867. §Weldon, Walter. 29 The Cedars, Putney, London, S.W.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡Wesley, William Henry.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. §§West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1851. *Western, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.
1870. §Westgarth, William. 3 Brunswick Gardens, Campden Hill, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
Westhead, John. Manchester.
1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster, Scotland.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1860. §Weston, James Woods. Seedley House, Pendleton, Manchester.
1864. §Westropp, W. H. S., M.R.I.A. 2 Idrone-terrace, Blackrock, Dublin.
1860. ‡Westwood, John O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1853. ‡Wheatley, E. B. Cote Wall, Merfield, Yorkshire.
Wheatstone, Sir Charles, D.C.L., F.R.S., Hon. M.R.I.A., Professor of Experimental Philosophy in King's College, London. 19 Park-crescent, Regent's Park, London, N.W.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1853. ‡Whitaker, Charles. Milton Hill, near Hull.
1859. *Whitaker, William, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1866. §White, Charles, F.R.G.S. Barnesfield House, near Dartford, Kent; and 10 Lime-street, London, E.C.
1864. §§White, Edmund. Victoria Villa, Batheaston, Bath.
1837. ‡White, James, M.P., F.G.S. 14 Chichester-terrace, Kemp Town, Brighton.
White, John. 80 Wilson-street, Glasgow.
1859. ‡White, John Forbes. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. §White, Laban. Blandford, Dorset.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1858. ‡Whitehead, J. H. Southsyde, Saddleworth.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Belmont, Rawtenstall, Manchester.
1855. *Whitehouse, Wildeman W. O. Roslyn House Hill, Pilgrim-lane, Hampstead, London, N.
Whitehouse, William. 10 Queen-street, Rhyl.
1871. §Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.
*Whiteside, James, M.A., LL.D., D.C.L., Lord Chief Justice of Ireland. 2 Mountjoy-square, Dublin.
1866. §Whitfield, Samuel. Golden Hillock, Small Heath, Birmingham.
1852. ‡Whitla, Valentine. Beneden, Belfast.

Year of Election.

Whitley, Rev. Charles Thomas, M.A., F.R.A.S. Bedlington, Morpeth.
1865. ‡Whittern, James Sibley. Wyken Colliery, Coventry.
1870. §Whittern, James Sibley. Walgrave, near Coventry.
1857. *Whitty, John Irwine, M.A., D.C.L., LL.D., C.E. 94 Baggot-street, Dublin.
1863. *Whitwell, Thomas. Thornaby Iron Works, Stockton-on-Tees.
*Whitworth, Sir Joseph, Bart., LL.D., D.C.L., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.
1870. §Whitworth, Rev. W. Allen, M.A. 185 Islington, Liverpool.
1865. ‡Wiggin, Henry. Metchley Grange, Harbourne, Birmingham.
1854. §Wight, Robert, M.D., F.R.S., F.L.S. Grazeley Lodge, Reading.
1860. ‡Wilde, Henry. 2 St. Ann's-place, Manchester.
1852. ‡Wilde, Sir William Robert, M.D., M.R.I.A. 1 Merrion-square North, Dublin.
1855. ‡Wilkie, John. 24 Blythwood-square, Glasgow.
1857. ‡Wilkinson, George. Monkstown, Ireland.
1861. *Wilkinson, M. A. Eason-, M.D. Greenheys, Manchester.
1859. §Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay
*Willert, Paul Ferdinand. Booth-street, Manchester.
1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.
1870.§§William, G. F. Copley Mount, Springfield, Liverpool.
*Williams, Caleb, M.D. 73 Micklegate, York.
Williams, Charles James B., M.D., F.R.S. 49 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 78 Park-street, London, W.
1864. *Williams, Frederick M., M.P., F.G.S. Goonvrea, Perranarworthal, Cornwall.
1861. *Williams, Harry Samuel. 49 Upper Brook-street, Grosvenor-square, London, W.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1871. §Williams, James, M.D. The Mount, Malvern.
1870. §Williams, John. 10 New Cavendish-street, London, W.
Williams, Robert, M.A. Bridehead, Dorset.
1861. ‡*Williams, R. Price.*
1869. §Williams, Rev. Stephen. Stonyhurst College, Whalley, Blackburn.
Williams, Walter. St. Alban's House, Edgbaston, Birmingham.
1865. ‡*Williams, William M.*
1850. *Williamson, Alexander William, Ph.D., F.R.S., F.C.S., Professor of Chemistry, and of Practical Chemistry, University College, London. 12 Fellows-road, Haverstock-hill, London, N.W.
1857. ‡Williamson, Benjamin. Trinity College, Dublin.
1863. ‡Williamson, John. South Shields.
*Williamson, Rev. William, B.D. Datchworth Rectory, Welwyn, Hertfordshire.
Williamson, W. C., Professor of Natural History in Owen's College, Manchester. Fallowfield, Manchester.
Willis, Rev. Robert, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 23 York-terrace, Regent's Park, London, N.W.; and 5 Park-terrace, Cambridge.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1857. ‡Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.
1859. *Wills, Alfred. 43 Queen's Gardens, Bayswater, London, W.
1865. ‡Wills, Arthur W. Edgbaston, Birmingham.
Wills, W. R. Edgbaston, Birmingham.

Year of
Election.

1859. §Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
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